With the Compliments of

Prof. Edward Orton.

REPORT

OF THE

GEOLOGICAL SURVEY

OF OHIO.

VOLUME V.

ECONOMIC GEOLOGY.

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PREFACE.

The plan of a volume to be entitled "Economic Geology," and which should form one of the final reports of the Geological Survey of the State then in progress, was announced as early as 1870 by my predecessor, Professor J. S. Newberry. The scope of the volume as originally designed can be seen in his first formal announcement of it, Report of Progress, 1870, page 12. Its prospective contents are there stated in the following terms, viz.: "The geology and technology (mining, manufacture and uses) of our Coals, Iron Ores, Clays, Salts, Limes, Hydraulic Cements, Petroleum, Gypsum, Building Stones, etc., etc."

Frequent references to this volume are made in subsequent reports of the Survey. For example, in volume II, Geology of Ohio, page XIII, Professor Newberry speaks of it as "intended to include an exhaustive and accurate review of all our mineral staples, Coal, Iron, Peat, Clay, Salt, Oil, Building Material, etc." He further describes it as designed "to determine the quality, uses and best methods of manufacture of our mineral staples, not only by means of the ordinary chemical analyses, but by carefully gathering the results of all the trials to which they have been subjected in real life and by original experiments made with an amount of material, and under such conditions as would afford a practical and working test of each."

To many, and probably to most of that portion of our citizens who have taken a definite interest in the progress of the Survey, the volume thus announced has seemed certain to be the most interesting and valuable of the entire series, and, accordingly, after the publication of the reports of the Survey had been interrupted for several years through the failure of successive legislatures to provide for the issue of the third volume of Paleontology, a bill to complete the volume on Economic Geology was passed by the Legislature in 1882, with but little opposition, and, in 1883, provision was made to publish it when completed.

The volume herewith presented derives its title as well as its general scope from the plan projected by Professor Newberry, but if this plan could have been worked out by its distinguished author the result would have been a very different volume from the present, and, assuredly, a much more valuable one. Of the field mapped out in the comprehensive program already quoted, there are entire sections into which I have not been able to enter, and in those subjects which the present volume discusses, the limitations arising in part from want of time and means for investigation are to be found on every page.

In treating the subjects included in the present volume, I have steadily endeavored to keep within the limits imposed by the title and plan of the work as fixed by my predecessor and by the action of the Legislature, and, therefore, no discussion of the general geology of the State, as such, is to be looked for in these pages. But inasmuch as our mineral wealth is chiefly centered in the Coal Measures, a discussion of the economic elements of the Ohio scale will largely consist in a discussion of the geology of the Coal Measures, and principally of the

Lower Coal Measures. In so far, therefore, as the title suggests a distinction between general and economic geology, it is, to a certain extent, misleading. Any properly written account of the geology of a Coal Measure county would be in the main a chapter of economic geology, and a considerable part of the materials furnished in the three volumes of the geology of Ohio, already issued, would by a true classification fall under the same head.

The order of arrangement of the Coal Measures, involving the persistency and extent of the leading elements, I have counted strictly within the province of economic geology, and I have accordingly devoted a large space in the present volume to the interpretation of the order of the Lower Coal Measures. Coal seams and beds of iron-ore and fire-clay have characters of their own. In entering an undeveloped field, it is not enough to know that the openings made show coal, ore or clay of good volume and quality, but in order to warrant any safe forecast as to the persistency of these elements, we need to know the horizons to which they are severally to be referred. A good showing at one horizon would stand in a very different light from an equally good showing in another, as a basis for the investment of capital.

The best single service that the present volume can claim to have rendered is in the determination of the leading horizons throughout the entire coal field of the State. Several important changes have been made in the reading of the record. The Leetonia coal has been shown to be the Lower Kittanning seam or the first above the Ferriferous limestone. The Canfield cannel seam has been shown to belong to the Ferriferous limestone horizon. The Hammondsville Strip Vein has been shown to be the Middle Kittanning seam, and the Clay Vein coal of the Ohio Valley, the Lower Kittanning seam, or the first and second seams, respectively, above the Ferriferous limestone. The Steubenville Shaft coal has been referred to the Lower Freeport horizon; the Osnaburg coal of Stark county, and the Pike Run or Dennison coal of Tuscarawas county, which are the same seam, are shown to be Middle Kittanning and not Upper Freeport in age. The Carbondale coal of Athens county, has been so clearly proved to be the Nelsonville seam that the question of its age cannot longer be regarded as an open one. The Waterloo coal of Lawrence county has been shown to be the Upper Freeport seam and not the Middle Kittanning. The clay seam of East Liverpool and the Upper Ohio Valley has been proved to be the Kittanning clay and not the Lower Mercer. The Blackband ore of Stark and Tuscarawas counties has been proved to occupy the horizon of the Upper Freeport coal. The Putnam Hill limestone has been shown to be a companion seam to the Ferriferous limestone, and not this limestone itself, underlying it and almost alternating with it in its appearance, in the girdle of the old coal gulf.

As a matter of course, a great number of other changes will follow those already named. It would be too much to expect that all of these changes should be at once adopted. The leading ones have already recommended themselves to those who are practically engaged in the development of the various fields, and the new order is proving itself a safe and certain guide in all recent explorations. In regard to its final acceptance I entertain no doubt.

It is a matter of regret to me that I have been obliged to leave entire sections even of the Ohio coal field without any adequate notice in the present volume. The Barren Measures, 400 to 500 feet in thickness, and containing a number of valuable

elements, have received no notice whatever. The Upper Coal Measures, 400 feet in thickness, which almost rival the Lower Measures in importance, are also passed without any methodical discussion, aside from a single short chapter devoted to a single coal seam. Even the lowermost portion of the Lower Coal Measures I have not found time to study in a systematic way, but, so far as this section is concerned, the facts of the present economic development in the only important fields are clearly and fully given. I can only say that I have done what I could with the time and means at my disposal. Being unable to cover the field, I was obliged to choose what portion I should occupy. I selected that portion of the Lower Coal Measures included between the Mercer horizon and the Mahoning sandstone as clearly the most important mineral-producing belt of the State. But even in this part of the scale, there are some dark corners still left, especially in Southern Ohio. Its main elements, however, are set in so plain an order that he who runs may read.

The same explanations must cover, in the main, the omission of several other subjects that certainly deserve a place in a volume treating of the economic geology of the State. Among these must be named *lime-production*, a large and growing interest in Ohio, and which has been treated only incidentally here; *cement-manufacture*, which, though at present developed to but small extent, is likely soon to attain much greater importance; the *production of gypsum*, which is, however, confined to one locality; and, finally, the *production of salt, bromine, petroleum and inflammable gas*, substances which are in almost all cases associated in their appearance in Ohio. The manufacture of salt has long been carried on in the State in a very large way.

A chapter has been prepared on this last-named group of substances, with special reference to the deep borings for natural gas in which so much interest is now taken and so much money expended in various sections of the State, but it is found impossible to include it here, for the reason that the volume has already grown beyond proper limits in size.

This chapter, embodying as it does the results of all the more important explorations for oil and especially the facts accumulated in the recent very extensive and expensive drillings for natural gas, is believed to be filled with timely and practical information which can be made to do good service in directing, restricting or discouraging the expenditure of money in this novel and enticing quest. The chapter will be presented to the Legislature at its next session, with the request that it be published as a supplement to the volume now issued.

The chemical work herein reported will be recognized by intelligent readers as one of the most important features of the present volume. The analyses are based on a different system of sampling from any heretofore used in the geological work of the State, and, representing average instead of exceptional values, they bring to light the real characteristics of our several coal seams, and can be safely followed as practical guides in the fields which they occupy. It is coming to be clearly recognized that the highest chemical skill is valueless in this line of investigation, unless the samples on which it is exercised are taken by some system which will make it certain that they really and adequately represent the seams from which they are derived.

Without the promise of Professor Lord's coöperation in this department, I should not have ventured upon the preparation of the volume, and without the

cordial fulfillment of this promise, and more, on his part, the volume would lack much of its present value. His chapter on Iron Manufacture in Ohio will be recognized as the most important paper yet published upon this subject.

There is no person in the State so well acquainted with the various systems of mining in force in Ohio as Hon. Andrew Roy, late State Inspector of Mines. The chapter which he has prepared on this subject will be found replete with valuable information.

I am indebted to E. McMillin, Esq., Superintendent of the Columbus Gas Works, for a chapter giving all available facts on the production of gas from Ohio coals. Mr. McMillin is widely known as one of our best trained and most successful managers of gas-works, and his contribution is one of real scientific and practical value in this field.

Professor G. Frederick Wright, of Oberlin, contributes an interesting chapter, accompanied by a map, upon the Glacial Boundary in Ohio. The author is recognized as one of our most accomplished glacialists, and his services have been brought into requisition in the Geological Surveys of the United States and of Pennsylvania, as well as in Ohio. If any question is raised as to the connection of this subject with economic geology, such question will be found answered in the chapter itself, in which the relations between soils, brick-clays, gravel-beds and water-supply with the glacial deposits are clearly shown.

For the balance of the work, both in field and office, I have been obliged to rely, in addition to my own labors, mainly upon young men with little or no previous practical training, inasmuch as the services of such could be obtained at much lower rates of compensation than experienced geologists would demand, and inasmuch as the limited funds at my disposal required economy at every step. As a matter of fact most of them were students or recent graduates of the State University who had studied geology in my own class-room, and who were consequently acquainted with my methods and views. All of them proved faithful and efficient, and several have acquired experience enough to fit them for independent work in our coal fields.

Their names are as follows :

J. N. Bradford, Mech. Eng.,	Frederick Keffer, E. M.,
C. Newton Brown,	Ellis Lovejoy,
Edward C. Downerd,	Edward Orton, Jr., E. M.,
John J. Dun, E. M.,	Frederick W. Sperr, E. M.,

To this list the name of Prof. Albert A. Wright, of Oberlin, is to be added.

Mr. Brown was longer in service than any other, and the Survey is much indebted to his faithful and discerning work. The chapter on the Meigs Creek coal and the map accompanying it (map No. 9) are entirely of his authorship. This is the only field which has been reported upon with which I am not personally familiar. To Mr. Brown is owing the demonstration of the identity of the Nelsonville and Carbondale coals.

To Mr. Sperr, the credit belongs of working out the true place of the Steubenville Shaft coal, one of the best pieces of stratigraphical work recorded in the volume.

Edward Orton, Jr., has prepared two chapters of the volume, viz., the chapter on Clays, and that on the Coal Mines of Coshocton county.

Prof. Wright made a careful and discriminating study of Holmes county, and has recorded his work in the chapter that treats of its coal seams.

On six of the sheet maps that accompany the volume, viz., Nos. 4, 5, 6, 7, 8 and 9, there are laid down the areas actually occupied by the most important geological element or elements of the district represented. As to what the most important elements are, there can scarcely be any difference of opinion. The Kittanning coals in the northern counties and the Ferriferous limestone in the southern are universally recognized as far in advance of all other horizons in economic interest. Though known by different names, they constitute practically one continuous series, so that we now have an inner line of outcrop within the Coal Measures from the Ohio Valley as far northward as Stark county. From this point, eastward to the Pennsylvania line, the face of the country is so heavily overlain with drift that it is impossible to follow the formations in detail.

This division of the Coal Measures into distinct areas will be recognized by all students of our geology as a step in advance. It is, however, but *one* step where several need to be taken. The Mercer and the Freeport areas deserve to be added to those already represented.

Extreme accuracy is not claimed for these maps, but the general distribution of the coal and ore areas is adequately shown upon them, and they also indicate where mines and railroad extensions can be properly located. The revelations that they make as to the areas of our coals will, in some cases, prove surprising even to those best acquainted with the districts represented. In almost every case, the measured areas prove smaller than previous estimates had made them.

The acknowledgments which I owe for assistance of various sorts in the preparation of this volume are so numerous that I cannot undertake to make individual mention of them all. In every section of the State in which I have worked, I have received invaluable assistance from well-informed and public-spirited citizens. The information derived from such sources has been blended with knowledge otherwise obtained, but it constitutes no small part of the account of our mineral wealth which I have here undertaken to present.

There are, however, certain persons whose services, in connection with the volume, have been such that it would not be right to pass them by without particular mention.

First of all are to be named the Trustees of the State University, who, by their liberal policy, have rendered it possible for me to undertake and carry forward the work herewith presented, in connection with my college duties. During the last two years they have, from time to time, granted me such exemption from these duties as I have required in order to collect and arrange the materials of this volume. I desire to place upon record my high appreciation of their considerate action.

To Hon. T. C. Snyder, of Stark county, a member of the 65th General Assembly, is due the credit of introducing and urging the legislation by which the completion of this volume was provided for. To the same gentleman, aided by Hon. James Scott, of Warren county, is also due the introduction of the bill by which the present publication was secured.

To the following-named gentlemen I am indebted for special assistance in working out the several districts in which they reside or in the correction and criticism of the statements published in regard to these districts. While they have helped me to the facts which I have used, it does not follow that they will in all

cases adopt the constructions which I have placed upon these facts. In naming them, therefore, I do not, in any way, seek to represent them as committed to my interpretations of geological order or economic significance. The list includes Messrs. R. M. Haseltine and Jonathan Head, of Youngstown; William Wetmore, of Canfield; Anthony Howells, of Massillon; J. G. Chamberlain, of Leetonia; Andrew Lee, of Sherrodsville; William Smurthwaite, of Steubenville; Thomas Corcoran, of Corning; James Taylor, of New Lexington; Thomas M. Black, of Buchtel, and John Campbell, of Ironton.

The officers of the various railroad lines that cross or that give access to our coal fields have rendered important aid to the Survey by giving free transportation to myself and my assistants while engaged in this work. The appropriations made by the Legislature would have been quite inadequate for the unexpected amount of labor with which I found myself burdened had it not been for this liberal policy on the part of the railroads.

Special acknowledgments are due to the gentlemen named below:

Messrs. B. Dunham and G. J. Foreacre, Baltimore & Ohio R. R.; Orland Smith, Cincinnati, Washington & Baltimore R. R.; N. Monsarrat, Cleveland, Akron & Columbus R. R.; J. H. Devereux, Cleveland, Columbus, Cincinnati & Indianapolis R'y; Oscar Townsend, Cleveland, Lorain & Wheeling R. R.; M. D. Woodford, Cleveland & Marietta R. R.; M. M. Greene, Columbus, Hocking Valley & Toledo R'y; Sam. Briggs, Connotton Valley R'y; John Newell, Lake Shore & Michigan Southern R'y; J. M. Ferris, New York, Penn'a & Ohio R. R.; J. E. Martin, Ohio Central R. R.; Geo. Skinner, Scioto Valley Railway; J. E. Turk, Valley Railway; M. D. Woodford, Wheeling & Lake Erie R. R.

A few things remain to be said, which are of a somewhat personal character.

I gave a promise to members of the 65th General Assembly, that this volume, for the preparation and publication of which they had made the necessary provision, should be issued in 1883, so that its distribution should be in their hands. Subsequent to the adjournment of the Legislature, however, I was made to believe that I could render a better service to the State by accepting for the summer a place on what is known as the Mining Screen Commission, provision for which was made by the same General Assembly, and the work of which was in part germane to my investigations in economic geology, than by pressing the volume to immediate issue. By this delay, the volume has gained 60 per cent. upon my original estimate of 700 pages, the whole having been kept, however, within the appropriations made for a volume of that size. It is a pleasure to add that 1000 copies of the volume are to be placed on sale in the Secretary of State's Office, at the actual cost of publication. If the whole edition were so placed, it would ensure a much better distribution than the previous volumes of the Geological Survey have had.

I bespeak for the volume a kindly and candid reception. Its deficiencies of plan and execution, which are many, are better known to me than they will be to any critic. The responsibility for the volume has, however, been so placed by the Legislature that I cannot charge them over to any other person or party. Draughtsman,

engraver and printer have done all that was asked of them, and the final responsibility for all defects and errors rests with me. In undertaking to state such a multiplicity of facts as the present volume includes, it cannot be but that errors will be made. Some minor ones have already been discovered. I may, perhaps, justly ask that account shall be taken of the fact that I have been obliged to do this work in conjunction with the duties of my professorship in the State University, and also by the fact that I have been held within close limits as to expenditure by an appropriation that was designed for a much smaller volume. The style of execution adopted for maps and illustrations must be considered with this fact in view. It was required that the volume on economic geology should be published economically if at all.

So far as I have treated of our mineral fields, I have aimed to give uncolored statements, statements that will prove equally fair to the buyers and the sellers of mineral lands. We are so accustomed to exaggeration and overstatement in the description of mineral wealth that when the sober truth is told, it sometimes seems an intentional disparagement. Time will undoubtedly show that some of our present estimates are too low and others will be found too high, but from errors of this sort, none are exempt. E. O.

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CORRECTIONS AND ADDITIONS.

(Of the typographical errors that occur in the volume, most are of a sort that will occasion no obscurity. A few are noted that would prove misleading or confusing.)

Page 83, 14th line from bottom, for Freeport, read Kittanning.
Page 142, 16th line from bottom, for Bellaire, read Meigs Creek or Barnesville.
Page 283, 5th line from bottom, before Barnesville, read Meigs Creek or.
Page 654, 6th line from top, for 100, read 10.
Page 714, 16th line from top, for ½, read 1-12.

An unfortunate omission occurs in the list of the Early Blast Furnaces of Ohio, on page 450, and one or two corrections need to be made.

The list should begin as follows:

1803, Hopewell Furnace, Poland, Mahoning Co., Daniel Heaton.
1806, Montgomery Furnace, Struthers, Mahoning Co., Montgomery and Struthers.
1807, Rebecca Furnace (Dale), New Lisbon, Columbiana Co., Gideon Hughes, kidney and limestone ores.

Hopewell Furnace was sold in 1807 to Montgomery, Clendennin & Co., and it becomes the Yellow Creek Furnace, which heads the list on page 450.

The list should be supplemented by the insertion of the following item:

1840, ——— Furnace, Calcutta, Columbiana Co., Arnold Downey, kidney and block ores.

ECONOMIC GEOLOGY OF OHIO.

CHAPTER I.

THE STRATIGRAPHICAL ORDER OF THE LOWER COAL MEASURES OF OHIO.

BY EDWARD ORTON.

The classification of the coal measures of the Northwestern portion of the Appalachian field, which was proposed by Henry D. Rogers in the reports of the First Geological Survey of Pennsylvania (vol. II, part I, p. 16), has been accepted and followed, at least in its main features, by all of the geologists that have subsequently worked in the territory to which this classification applies.

Rogers recognized five sub-divisions or sub-formations of the rocks of this series, and to these divisions he assigned the following names, viz.:

5. Upper Barren Measures.
4. Upper Coal Measures.
3. Lower Barren Measures.
2. Lower Coal Measures.
1. Seral Conglomerate.

To the lowest sub-division, viz., the Conglomerate, a thickness of 500 feet was assigned in Western Pennsylvania, to the Lower Coal Measures, a thickness of 600 feet; to the Lower Barren Group, a thickness of 500 feet; to the Upper Coal Measures, 250 feet, and to the Upper Barren Group, 950 feet.

The vertical boundaries of the several groups were quite defi-

nitely fixed. The most uncertainty prevailed in regard to the lowest division. A conglomerate formation is generally liable to abrupt changes in its composition, and this particular formation proves no exception to the rule. No easily distinguishable stratum could be found to serve for its lower boundary, and more or less confusion of thought is shown in regard to what the formation really included.

The Brookville coal was taken, according to Lesley, as the true base of the Lower Coal Measures, and the Upper Freeport coal for the upper limit of this division.

The third group has for its base the top of the Upper Freeport coal, and for its summit the bottom of the Pittsburgh seam.

The fourth division extends from the Pittsburgh coal to the Waynesburgh coal, including both.

The fifth division takes in the various rock formations above the Waynesburgh coal as they occur in Western Pennsylvania.

The Seral Conglomerate was always distinctly recognized and described as a proper and normal member of the Coal Measures, shown to be so by its frequently "containing regular and even thick beds of coal, identical in composition with the seams of the generally productive overlying group." The Sharon coal in particular was always placed beneath the Conglomerate, as the term was then understood, and several other seams were also counted as sub-conglomerate, or at least inter-conglomerate seams.

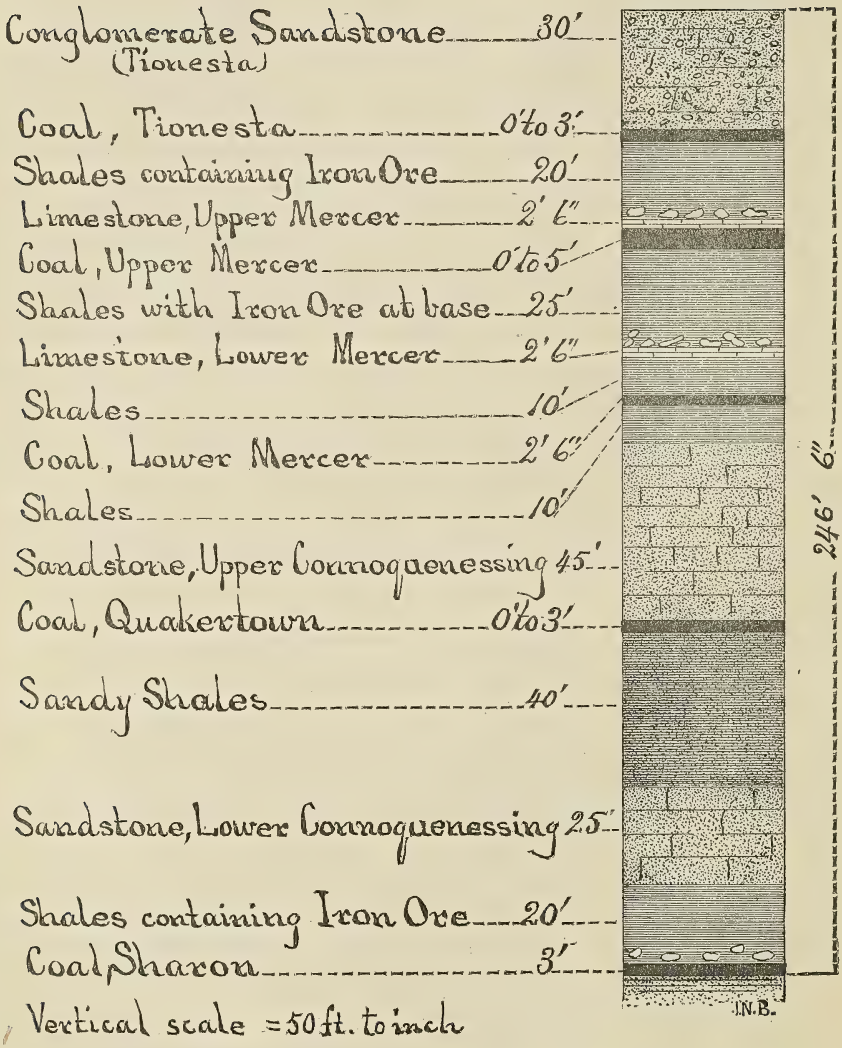
The second Geological Survey of Pennsylvania, which is now in progress, has in the main confirmed and established these earlier subdivisions of the coal measures. In particular, the constitution of the Seral Conglomerate of Rogers has been clearly worked out. This has been shown to be a complex formation, consisting of three main sandstone or conglomerate strata, the lowest of which, viz., the Sharon Conglomerate, directly underlies the Sharon or lowest coal seam. The middle stratum, often split into two and sometimes holding a thin coal seam between the two ledges, is known in Pennsylvania as the Connoquenessing sandstone, and in Ohio as the Massillon sandstone. Above this stratum occurs the well-marked horizon of the Lower and Upper Mercer Limestones. Each of these limestones is underlain by a coal seam, and each frequently bears an iron ore. Above the Mercer limestones is found the third and last of the sandstone strata already referred

to. Neither this stratum nor the one below it is characteristically a conglomerate in Western Pennsylvania, but both are best described as conglomeritic sandstones. To this upper stratum, various names have been assigned. In the reports of the First Survey it was frequently called the Tionesta Sandstone. In the reports of the Second Survey it is designated not only by the old name, but by two additional names, viz., the Piedmont Sandstone and the Homewood Sandstone, the latter of these being most frequently used.

These several elements constitute the Conglomerate Group, according to the most recent statements. A few feet above the Homewood Sandstone in normal sections, the Brookville coal, or Coal A of Lesley's earlier series, is found. The composition of the group is more clearly shown in the following diagram, Fig. 1, which is copied from Professor I. C. White's Report on Mercer county, Q 3, Second Pennsylvania Survey, page 33. The diagram is designed to give the typical section of the Conglomerate or Inter-conglomerate measures in Mercer county. The average actual thickness of this division in the counties bordering on the Ohio line is about 250 feet.

It will be observed that four regular coal seams, viz., the Sharon coal, the Quakertown coal, the Lower Mercer and the Upper Mercer coals, have a place in this series, three of them being widely known and worked, and one of them, the Sharon coal, being of great economic importance.

FIGURE I


Conglomerate Sandstone 30′
(Tionesta)
Coal, Tionesta 0′ to 3′
Shales containing Iron Ore 20′
Limestone, Upper Mercer 2′ 6″
Coal, Upper Mercer 0′ to 5′
Shales with Iron Ore at base 25′
Limestone, Lower Mercer 2′ 6″
Shales 10′
Coal, Lower Mercer 2′ 6″
Shales 10′
Sandstone, Upper Connoquenessing 45′
Coal, Quakertown 0′ to 3′
Sandy Shales 40′
Sandstone, Lower Connoquenessing 25′
Shales containing Iron Ore 20′
Coal, Sharon 3′
246′ 6″
J.N.B.
Vertical scale = 50 ft. to inch

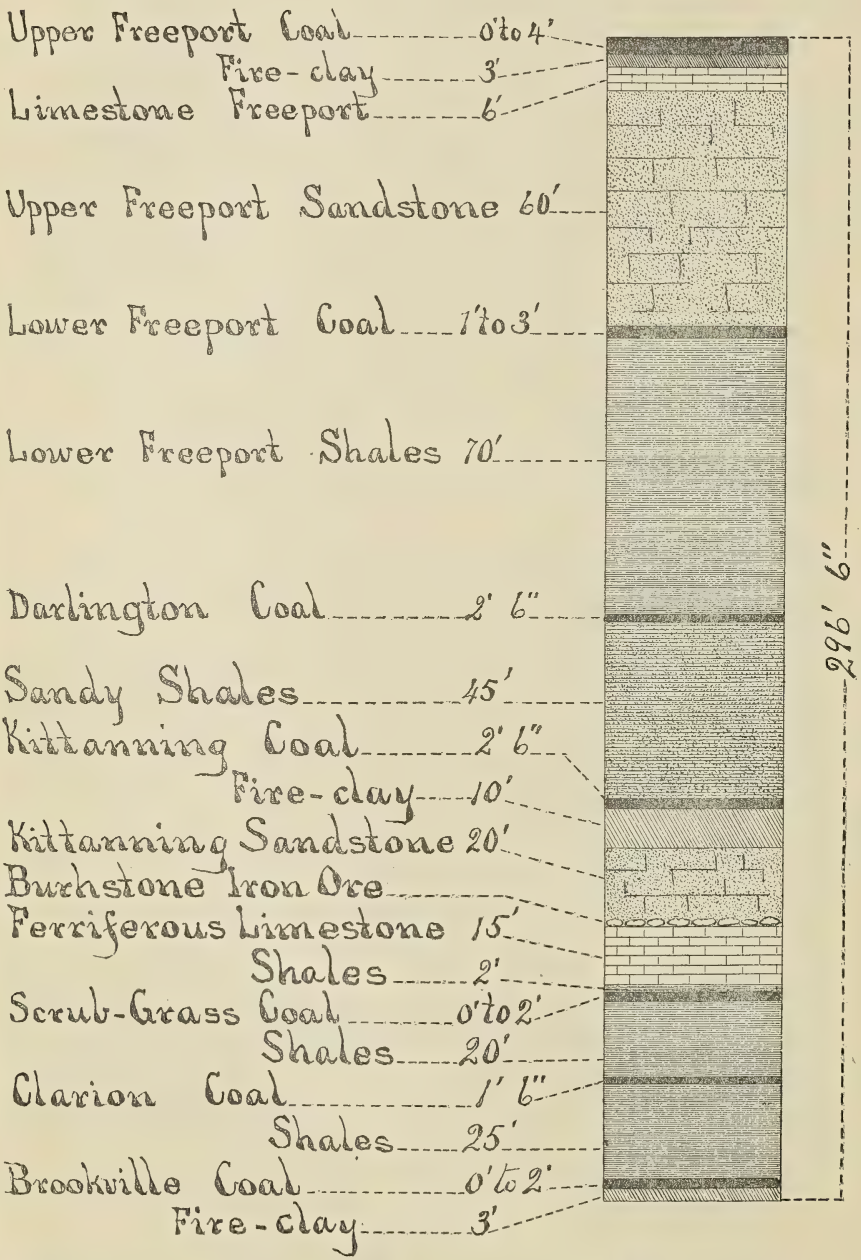
The second of Rogers's sub-divisions, viz., the Lower (productive) Coal Measures, has for its boundaries, as will be remembered, the Brookville coal and the Upper Freeport coal, both being included in the series. As understood by the geologists of the First Survey, it embraced the following principal elements, viz.:

Upper Freeport Coal (Coal E).
Freeport Limestone.
Lower Freeport Coal (Coal D).
Freeport Sandstone.
Kittanning Coal (Coal C).
Buhrstone Ore.
Ferriferous Limestone.
Scrub-grass Coal.
Clarion Coal (Coal B).
Brookville Coal (Coal A).
(Geology of Pennsylvania, H. D. Rogers, vol. II, part I, pp. 475–6.)

To the elucidation of this very important division, the Second Pennsylvania Survey has devoted a great deal of labor, and while the order of arrangement given above has been abundantly confirmed, the series has been expanded by the introduction of several elements previously unrecognized. There is not exact agreement among the excellent geologists that have been employed in the work as to the minute composition of the group in all its parts, but any one of the general sections that they have furnished will be found to cover the essential facts. The section represented in the following diagram, Fig. 2, is taken from Professor White's Report on Lawrence county, Q 2, page 22.

In confirmation and establishment of this general section, the following diagram, Fig. 3, represents the actual section that is found at New Brighton, on the Beaver river. A section obtained at Smith's Ferry, near the Ohio line, is shown in Fig. 4. Both of these figures are taken from White's Report on Beaver county, Second Pennsylvania Survey, Q, page 41.

FIGURE II



Vertical scale 50 ft. to inch

J.N.B. Del.

FIGURE III

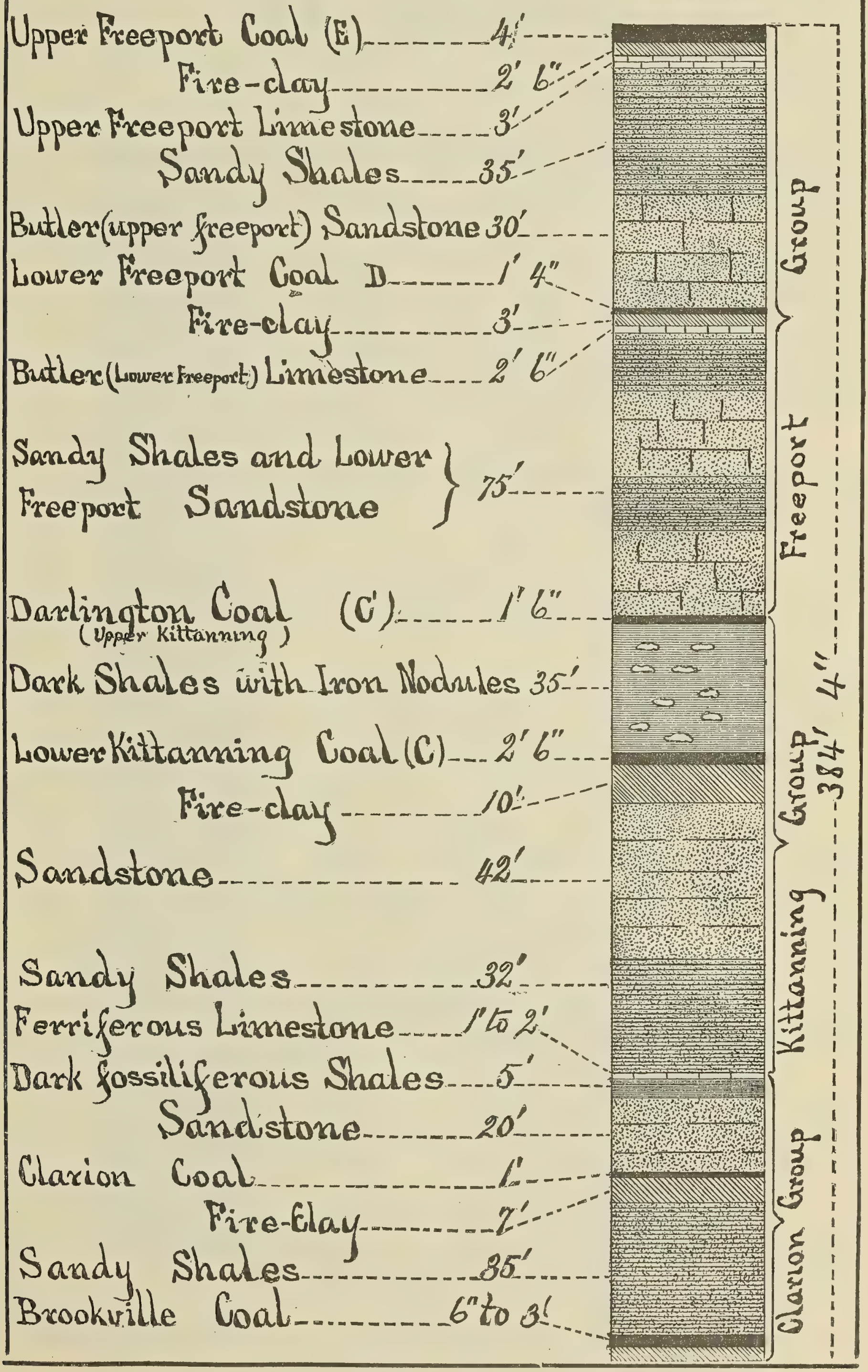
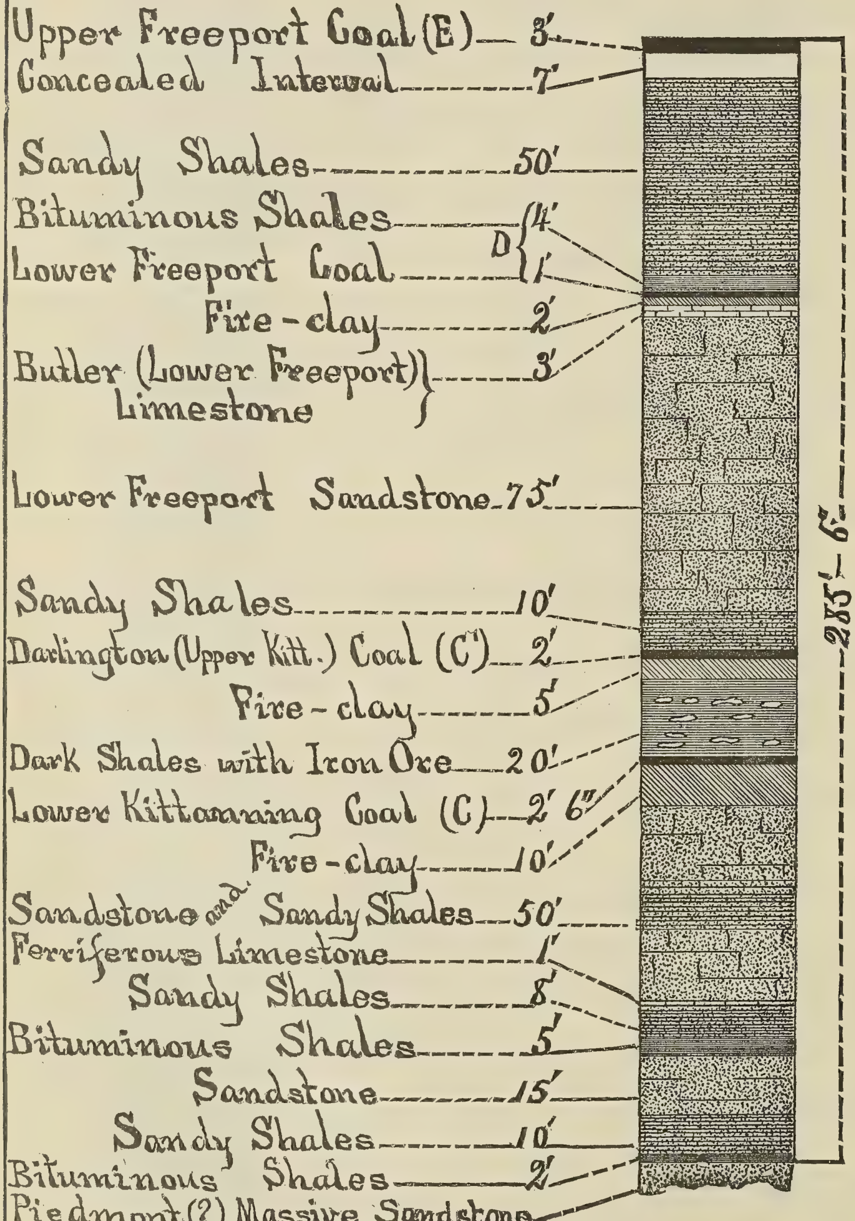

Upper Freeport Coal (E) 4′
Fire-clay 2′ 6″
Upper Freeport Limestone 3′
Sandy Shales 35′
Butler (upper freeport) Sandstone 30′
Lower Freeport Coal D 1′ 4″
Fire-clay 3′
Butler (Lower Freeport) Limestone 2′ 6″
Sandy Shales and Lower Freeport Sandstone 75′
Darlington Coal (C′) 1′ 6″
(Upper Kittanning)
Dark Shales with Iron Nodules 35′
Lower Kittanning Coal (C) 2′ 6″
Fire-clay 10′
Sandstone 42′
Sandy Shales 32′
Ferriferous Limestone 1′ to 2′
Dark fossiliferous Shales 5′
Sandstone 20′
Clarion Coal 1′
Fire-Clay 7′
Sandy Shales 35′
Brookville Coal 6″ to 3′
Freeport Group
Kittanning Group
Clarion Group
384′ 4″

FIGURE IV



Vertical scale 50 feet to the inch

J.N. Bradford Del.

The composition of these two sub-divisions of the coal measure rocks, as they occur in Western Pennsylvania, has thus been shown. The order of arrangement that has here been determined by the most thorough and the most closely connected stratigraphical work yet done in the United States, embodying as it does the harmonious results of a considerable number of well-trained geologists, who have scarcely been limited by either time or money in the prosecution of their work, may be counted settled.

But the order of the coal measure rocks in Western Pennsylvania is in all respects identical with the order of these rocks in Eastern Ohio. The sections that have been selected to represent this order were all taken from near the boundary line between Ohio and Pennsylvania, and the facts illustrative of this order are found equally on both sides of the line.

The true sequence of the various beds of coal, limestone, iron ore, clay, shale, sandstone and conglomerate that make up these divisions, is a fact of nature, to be determined by a sufficient amount of geological exploration and geological sagacity, and when once clearly determined, it is determined finally, like the geographical facts of latitude and longitude, for example.

But the work of classifying these several facts, and of arranging the strata in groups, larger and smaller, is a task of very different character. The aim in all such schemes, of course, is to apprehend and indicate the salient features in the history which the rocks record, but in point of fact, all are arbitrary and artificial to a greater or less extent, and no geological classification can be counted final in the same sense in which a geological section can be so counted.

The order of sequence of the coal seams that have been enumerated, for example, has now been definitely ascertained, and it is not therefore liable to be replaced by some other order or to be materially changed, but the division of these seams and of the strata associated with them into the two great groups that have been named above, viz., the Conglomerate Measures and the Lower Coal Measures, rests on a very different foundation, and may well enough be called in question. It is quite certain that such a division would never have been made on the facts that occur in Western Pennsylvania. It was only by the establishment or supposed establishment of equivalency between the varied series of the lowest coal measures in the western part of the State with

the great Pottsville Conglomerate of Eastern Pennsylvania that the name Conglomerate Group came to be applied to these lower strata.

Even though fully accepting this identification as a matter of geological history, it is still open to the working geologist to discard the sub-divisions that have been established upon it, and to count all the coal seams, enumerated above, as belonging to one unbroken series. In point of fact, there is no more marked separation between the highest coal seam of the Conglomerate series and the lowest of the Productive Measures than can be found between two coals of the latter sub-division.

Newberry has always insisted upon counting all of the coal seams of Eastern Ohio, from the Sharon coal to the Upper Freeport coal, inclusive, as belonging to the Productive Measures, and Lesley has distinctly intimated in recent publications of the Second Pennsylvania Survey that he holds a similar view, at least so far as the western part of that State is concerned. (See Report on Beaver County, Q, p. 65.)

In the present report, the view of Newberry will be adopted as the most serviceable for the field with which we are dealing, and all of the coal seams named in the two general tables already given (Figures I and II), will be considered as included in the Lower Coal Measures. This departure from the present Pennsylvania classification consists simply in the removal of a line of division which has no natural prominence in the coal measure rocks of Ohio.

The composition of the conjoined series is repeated below so far as the leading elements are concerned:

24. Upper Freeport Coal.
23. Upper Freeport Limestone.
22. Upper Freeport Sandstone.
21. Lower Freeport Coal.
20. Lower Freeport Limestone.
19. Lower Freeport Sandstone and Shale.
18. Upper Kittanning Coal.
17. Lower Kittanning Coal.
16. Kittanning Clay.
15. Kittanning Sandstone.
14. Ferriferous Limestone and Buhrstone Ore.
13. { Scrub Grass Coal.
    Clarion Coal.
12. Brookville Coal.
11. Homewood Sandstone (top of Pottsville Conglomerate).
10. Tionesta Coal.

9. Upper Mercer Limestone and Ore.
8. Upper Mercer Coal.
7. Lower Mercer Limestone and Ore.
6. Lower Mercer Coal.
5. Connoquenessing Sandstone (upper).
4. Quakertown Coal and Shales.
3. Connoquenessing Sandstone (lower).
2. Sharon Coal and Shales.
1. Sharon Conglomerate.

It will be remembered that this series has been brought directly up to the Ohio boundary. It has even been followed across the boundary by the geologists of the Pennsylvania survey for the purpose of comparing the formations of some of the border counties of the two States. It belongs in all respects as much to Eastern Ohio as to Western Pennsylvania.

The purpose of the present chapter is to trace this series from the Pennsylvania line westward and southward through the State, and thus to secure as firm ground for the identification and correlation of the several elements of economic value which it contains as the present state of our knowledge will allow.

The series cannot of course be followed as a whole. The natural sections which occur seldom exceed 300 feet in vertical range, and for the most part we are confined to much shorter sections, but there are several elements in the series so well characterized, that they can be identified with comparative ease and certainty wherever they are found.

In addition to these single elements, there are some distinct *groups* of strata, including several of these well-marked and characteristic beds, and acquaintance with these groups may be made to greatly facilitate the work of tracing and identifying the series. The occurrence of a single stratum of the character referred to above is often enough to warrant the positive determination of the whole section in which it is found, but when one of these well-marked groups occurs, it "makes assurance doubly sure."

The single elements of the series upon which all men who have had occasion to study the Lower Coal Measures in either a scientific or a practical interest, have learned to rely with the greatest confidence, are the Limestones. The aggregate thickness of these limestones of the Lower Coal Measures is small; the thickness of the individual beds seems insignificant when compared with that of the strata that accom-

pany and enclose them, but it is beyond contradiction that these thin limestones are decidedly the most widely extended, and the most persistent of the entire series to which they belong. If a heavy deposit of conglomerate or pebble rock occurs in a section, it is sure of recognition, but if we undertake to trace a series by means of such a stratum, we are liable to failure. Conglomerates are the most variable and inconstant of all sedimentary formations. A bed of soft shale without a pebble may hold the place of a coarse and heavy conglomerate, but a mile or two away.

Limestones are hard and are therefore quite certain to attract attention in excavations and drill holes, and roadways. They are frequently replaced by flint, and the indestructible character of this substance ensures the ready recognition of the horizon to which it belongs. The color of a limestone is often characteristic, so that it can readily be distinguished from associated beds. If fossiliferous, this fact is likely to attract attention. Limestones are soluble in atmospheric waters, it is true, but even when dissolved at their outcrop, their place is none the less distinctly marked by the soils to which they give rise, and by the kinds of vegetation which they support.

Seams of coal have many advantages as guides to a knowledge of the true equivalence of sections. They are worked extensively and are therefore well known. The character of the coal, the number and kinds of the partings, the nature of the floor or roof, the color of the ash, and other similar facts often help us to carry coal horizons through hills or across valleys with as much confidence as visible continuity could inspire.

Beds of iron ore are worked more largely in some districts than even the coal seams, and thus they render a similar service. Occasionally a stratum of fire-clay has some peculiar character or quality, or some unusual volume by which it can be safely used in determining the order of two or more disconnected sections.

The sandstones on which so much popular reliance is placed in the identification of distant exposures of coal measure rocks, are in reality fallacious guides. Some of them, it is true, have distinctive marks of bedding or grain or color, by which they can be safely followed across intervals, but many of the identifications that are dependent on them are incorrect and misleading. Sandstones and conglomerates owe their existence to strong currents, by which their materials have been trans-

ported, but such currents have also erosive power, and it has often happened that by the removal of the thin beds of coal, clay, limestone, or ore that rest upon a stratum of sandstone, another stratum is let directly down upon the former in such a way as to defy separation at the point where the erosion has occurred. In other words, two sandstones, belonging to two distinct epochs of history, are made to appear as one undivided and continuous formation. Many cases of mistaken identifications in our series are due to such a line of facts as is set forth above.

It will be well to describe in brief terms the separate elements and the combined groups of the Lower Coal Measures, which are most useful in establishing the order of the great series to which they belong.

The limestones which are especially serviceable in tracing and identifying the various sections of the Lower Coal Measures are the following, named in descending order:

3. The Freeport Limestones (upper and lower).
2. The Ferriferous Limestone.
1. The Mercer Limestones (upper and lower).

These will be separately described. The combined group are the various beds of coal, iron ore, and fire-clay that accompany or include these several elements.

I. The Mercer Limestones.

(*a*) The Lower Mercer Limestone is a thin but wonderfully persistent bed that has long been known and used as a geological guide. It received its name (Mercer Limestone) from the geologists of the First Pennsylvania Survey, and took quite a conspicuous place in the sections reported by them from the northwestern portion of that State. (Geol. of Penna., H. D. Rogers, vol. II, part I, p. 476, et al.)

Much greater use has been made of it, however, by White and other geologists of the Second Pennsylvania Survey in establishing the order of the same portion of the coal-field. (See Report on Lawrence County, Q 2, page xxxi, et al.)

The value of the same stratum in maintaining the order of the lower portion of the series in Ohio was first clearly recognized and emphasized by Newberry. (Report of Progress, 1870, page 16, et al.) In volume II, page 130, he says of this limestone, that it may be traced

almost continuously from the Pennsylvania line to the Ohio, and that it is one of the most reliable and useful guides in the exploration of the country traversed by it.

Andrews pronounced it "everywhere a guide to the stratigraphical position of the rocks below it" throughout Hocking, Vinton and Jackson counties. (Report of Progress, 1870, page 93.)

It is generally known in Ohio in the regions where it occurs as the Blue Limestone, but the name fixed upon it by Newberry, viz., the Zoar Limestone, has also come into common use.

It is so nearly uniform in its leading characteristics that an adequate description of it in any one locality will answer without change for its whole extent.

In color it is dark-blue, occasionally almost black. In thickness, its usual range is from one to three feet, but it sometimes reaches a thickness of ten feet. It is frequently doubled, a second stratum coming in a few feet above the main bed. It does not lie in massive nor in even beds. It is often shaly in structure. It contains a notable quantity of iron, alumina and silica as a rule, but it is sometimes pure enough to be used for lime or even for furnace flux. It is highly fossiliferous, containing a considerable variety of the usual coal measure forms. It is especially characterized by the large stems of crinoids, which make one of its noticeable features. When replaced by flint, as it often is locally, the flint holds the fossils of the limestone.

The limestone is overlain throughout its whole extent by an excellent iron ore. The ore sometimes rests immediately on the limestone, and sometimes it is separated by a few feet of clay or shale. It is extensively worked in several districts of Ohio, and this fact makes the horizon much better known than it would otherwise be.

In addition to the ore borne by the limestone, it is also to be noted that a widely distributed coal seam belongs to the Lower Mercer horizon. The coal is sometimes directly covered by the limestone, but it often lies ten or fifteen feet below the latter. It is of mineable thickness in many localities, but it is worked mainly in country banks, so far as Ohio is concerned.

The Lower Mercer Limestone, thus definitely characterized as a stratum, and thus re-enforced by the well-known and widely-worked ore that it bears, and also by the coal seam that it covers, is, beyond question, the best marked formation in the Lower Coal Measures of Ohio,

and therefore the most available guide in establishing the order of this varied series of deposits.

(*b*) At an interval varying from twenty to forty feet above the limestone already described, another limestone, bearing another ore and covering another coal seam, is often found. It was first named by Rogers in the reports of the (first) Pennsylvania Survey, where it was designated the Mahoning Limestone (vol. II, part I, p. 567). This name has been dropped by the geologists of the Second Pennsylvania Survey for good reason, and the stratum is now known as the Upper Mercer Limestone. (White's Report on Lawrence County, Q 2, p. 57.) It has been recognized by all of the geologists who have worked to any extent upon the Lower Coal Measures of Ohio, but the only distinctive name that has been given to it here is the Gore Limestone. (Geol. of Ohio, vol. III, pp. 898 and 903.) Newberry refers to it in Mahoning county (vol. III, p. 795), Reed in Coshocton county (vol. III, p. 567), and Andrews in Perry and Muskingum counties (vol. III, pp. 823, 824 and 825).

It everywhere lacks the remarkable steadiness and continuity of the Lower Mercer Limestone, but in all other respects it is almost the exact counterpart of that well-marked stratum. It has, in the main, the same chemical composition, the same color, and other physical properties, and also the same fossils. In many instances the limestones can be distinguished only by their stratigraphical relations. But though generally agreeing with the lower limestone, it has some local peculiarities which serve to mark it for particular districts. In Central Ohio it is quite frequently a flint, constituting one of the main flint horizons of the series. Like the lower limestone it is occasionally, though rarely, found pure enough for furnace use. In such cases it assumes a lighter color, and this has sometimes led to its being confounded with a limestone that belongs above it in the series.

The ore that accompanies it is less valuable than the Lower Mercer ore, but its coal seam is in Ohio of at least equal value with the Lower Mercer Coal.

The interval between the limestones is generally occupied with fireclay and shale, but sometimes a sandstone occurs. The clay beneath the Upper Mercer coal is occasionally a workable bed, and another workable bed is found associated with the Lower Mercer Limestone in many localities.

From this brief description of the Mercer Limestones and of the

beds associated with them, it is seen how admirably adapted the limestones are as single elements, and the limestones with their ores and coals are, as combined groups, to become plain and trustworthy guides to the order of the Lower Coal Measures. When either of the limestones is found, it is hard to misinterpret the section in which it belongs, but when the six or more elements of the combined groups occur in a single section as they often do, there is no excuse for going wrong in the determination of its place in the general scale.

Too much stress cannot well be laid on these elements. The Lower Mercer horizon, in particular, is the one undisputed and indisputable element in the Lower Coal Measures of Pennsylvania and Ohio. Newberry asserts in words that have been already quoted, that it can be followed almost uninterruptedly from the Ohio river to the Pennsylvania line. At this point, the Pennsylvania geologists take it up, and follow it in unmistakable continuity through the western and northern counties of the coal field. In any system of correlation or coördination of the different portions of the Lower Coal Measures, this horizon must be taken as the common and accepted basis.

II. The Ferriferous Limestone.

The second of the series of widely extended strata that can be made to serve as a basis of identification throughout the Lower Coal Measures, to a greater or less degree, is the Ferriferous Limestone. This limestone is also the center of a group of beds, all of which are extensively worked, and therefore widely known, on account of their economic value. The group comprises, beside the limestone, the best iron ore, the largest clay deposit, and several of the most widely worked coal seams of the Lower Measures.

The limestone derives its name, Ferriferous, from the fact that it carries upon its upper surface an iron ore of great excellence, the basis of the old charcoal iron manufacture of Western Pennsylvania. (Geol. of Penna., Rogers, vol. II, part I, p. 491.) It has long been counted as a chief landmark in the geology of the districts in which it occurs. It was constantly used by Rogers in the construction of his sections (vol. II, part I, pp. 476, 484, 488, et al). It has held since that time the most important place in the determination of the order of every

district of Pennsylvania in which it occurs. The distances traversed in drill holes before reaching the lower coals or the oil sands are generally measured from the Ferriferous Limestone.

In the region of its best development, the limestone frequently reaches and carries a thickness of 15 feet. It sometimes rises to 20 or even 25 feet, but over large areas it ranges between 1 and 5 feet in thickness. Widely extended though it is, it is still subject to very rapid changes in volume, and even to frequent "wants." Generally, however, the stratum leaves some mark by which its place can be determined, even though the limestone has entirely disappeared.

It is the largest and most massive limestone of the Lower Coal Measures, and the only one pure enough to be used generally and in the large way as flux for iron furnaces. It is charged with a larger and more varied series of fossils than any other limestone of the Lower Coal Measures.

In color it is light-gray in its upper portions, and grayish-blue in its lower beds, but where the limestone is thin, the whole deposit is often of the latter shade.

It frequently bears a deposit of buhrstone or flint upon its upper surface, and this always makes a characteristic and permanent feature in the sections that contain it.

The buhrstone carries the most famous and valuable iron ore of the Lower Measures, to which reference has already been made.

The limestone sometimes exists in two distinct beds, separated by a thin stratum of fire-clay or shale. In some instances a small coal seam comes between the two beds. When thus separated, there is a marked distinction in color between the benches, as noted in a preceding paragraph.

White has called repeated attention to the fact, that whenever in Western Pennsylvania or Eastern Ohio the limestone grows thin, it exhibits "cone in cone" structure. (Second Penna. Survey, Q, p. 62, Q 2, p. 47, et al). No other horizon near this is known to have this peculiar structure, and therefore this mark when recognized becomes of practical service to any one engaged in tracing the series.

Two coal seams occur below the limestone and help to mark the general horizon. The place of one of these seams, which is known as the Scrub-grass coal, is directly beneath the limestone. The second or

Clarion coal is found from 15 to 30 feet below the limestone. By some of the Pennsylvania geologists the Scrub-grass coal is held to be a split from the Clarion. (Second Penna. Survey, V.V., p. 49). From this point of view the seams can well be designated the Lower and Upper Clarion coals. The lower seam has considerable economic value in Western Pennsylvania.

At a general distance of 30′ to 40′ above the limestone, but sometimes coming within 10′ to 15′ of it, there is found a coal seam that is as persistent and as largely worked as perhaps any seam of the lower series. It is the Kittanning coal of Rogers or the Lower Kittanning coal of the Second Pennsylvania Survey.

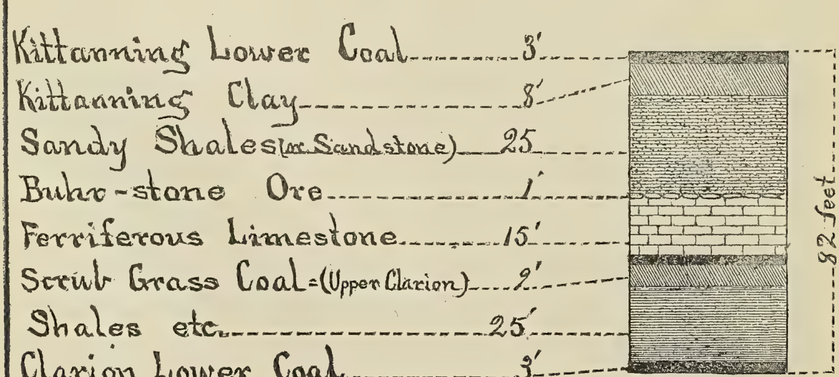
Below the Kittanning coal occurs the Kittanning clay, by far the most important deposit of its kind in Western Pennsylvania or Eastern Ohio. This seam is the basis of a large manufacturing industry in the Ohio Valley.

The elements named above, beginning with the Lower Kittanning coal, and ending with the Clarion coal, constitute what may be called the Ferriferous Limestone Group, a set of beds so well characterized, possessed of so much and so varied economic value, and so largely worked, that to follow them through the districts which they occupy is comparatively a plain and easy task.

The Ferriferous Limestone Group is represented in the accompanying general section, Figure V.

FIGURE V

FERRIFEROUS LIMESTONE GROUP



The Ferriferous Limestone is by no means as serviceable a guide for the entire coal field of Ohio as it has been shown to be in Western Pennsylvania. Great differences of opinion have existed in regard to what constituted its extension from Pennsylvania into Ohio, but although these questions have been definitely settled by the work of the recent Pennsylvania Survey, and although we now know which of the limestones of Mahoning and Columbiana counties are the proper and bodily continuations of the Ferriferous limestone of Lawrence and Beaver counties, Pennsylvania, there are still unsettled questions as to its westward extension through a number of counties. In Perry county, however, the limestone comes in again with its flint and ore, in unmistakable identity, and from this point southward to the Ohio river, it assumes the same central place in the Lower Coal Measures that it holds in Pennsylvania.

In thickness it does not reach the highest measures attained in Pennsylvania, ranging here between 2 and 8 feet, but in chemical composition, in fossil contents and in physical properties, it is the counterpart of the stratum in Pennsylvania. There is associated with it the same flint and ore, and it holds quite similar relations to the coal seams above and below it in the scale.

This limestone received the same name in Southern Ohio that it bears in Pennsylvania, viz., the Ferriferous Limestone, but it was by a happy accident, for at the time that its name was given, its identity with the seam to the eastward was not suspected by the geologists who were at work upon the coal measures. (Report of Progress, 1870, p. 61, etc.) It is commonly known in the region referred to as the Gray Limestone. It was also named the Hanging Rock Limestone in Vol. III, Geology of Ohio, p. 892, et seq.

The section of the coal measures of which the Ferriferous Limestone is the center, is thus seen to have had a symmetrical development on the opposite and widely separated sides of the basin in which and around which these various elements were formed, but a different state of things is found to have existed on the northern border of the basin. From the eastern side of Mahoning county to the center of Perry county, the Ferriferous limestone is either feebly developed and obscure, or is altogether wanting. So far as this one element is concerned, it has lost the character of a guide, and considered by itself it cannot be followed with ease or certainty across the interval. But in this very

interval where the Ferriferous limestone has grown weak and uncertain, another limestone of the same general character is found, which completely bridges the chasm, and by means of which we are able to maintain the unity of the series unbroken. This is the Gray limestone of Newberry and the original Putnam Hill limestone of Andrews.

Newberry made constant use of it as a guide through Stark, Tuscarawas, Holmes, and Coshocton counties. He conjoins it with the Lower Mercer limestone as to steadiness and extent, claiming for it as for the latter, that it can be followed almost uninterruptedly from the Pennsylvania line to the Ohio river. (Vol. II, p. 130). This claim cannot be substantiated in the light of what is now known, so far as the southward extension of it is concerned, but the limestone can be followed by frequently recurring and unmistakable exposures from the western side of Mahoning county as far as New Lexington, Perry county. It can be traced, indeed, further than this in both directions, but it is no longer a guide. It must itself be followed by the aid of other and better marked strata, the Ferriferous limestone being the most available of all.

The Putnam Hill limestone underlies the Ferriferous limestone by 15 to 50 feet. The usual interval may be counted 30 feet. A coal seam occurs directly below it, which is often of workable thickness and sometimes of great economic value. It is Coal No. 4, of Newberry, in the counties already named. A considerable bed of plastic clay is found below the coal, which is worked in some instances.

Like the Mercer limestones below it, the Putnam Hill limestone generally bears a block ore. The ore is of good quality and is sometimes mined in a small way.

In color, the Putnam Hill limestone is intermediate between the Lower Mercer and the Ferriferous limestones. If it were not for the contrast with the former, it could as properly be called blue as gray. If it had been contrasted with the Ferriferous limestone instead, it would certainly have received the former designation. It is indistinguishable from the better phases of the Upper Mercer limestone, and has often been confounded with it. Both of them figure in Ohio geology as gray limestones. When it is remembered that both of them overlie coals, that both bear block ores, that both are charged with the same species of fossils, it can be seen that the stratigraphical order may be necessary to determine to which horizon any given outcrop belongs.

The Putnam Hill limestone is from 25 to 50 feet above the Upper Mercer limestone, and from 50 to 90 feet above the Lower Mercer. The more common figures for these intervals would be, respectively, 40 and 70 feet.

By the aid of this steady and conspicuous stratum, it is possible to follow the horizon of the overlying Ferriferous limestone through the counties in which it fails as a regular deposit. The horizon is marked by occasional outcrops of limestone or flint, or by calcareous sandstones. Seams of ore and coal are also found at the same general level.

The Putnam Hill limestone does not extend into Pennsylvania, so far as is known, but its underlying coal can be followed across the border, where it becomes one of the well-known and widely extended seams of the Lower Measures. It is the Brookville coal of Rogers, Coal A of Lesley, with but little doubt.

The discussion of the Putnam Hill limestone at this time is incidental to the main purpose, which is to show the continuity of the more important Ferriferous limestone.

III. The Freeport Limestone (Upper).

The Freeport Group is the third in ascending order of the several series which extend widely through the Lower Coal Measures, and of this group the Upper Freeport Limestone is the most constant and well marked element. Like the limestones already described, it was first named by the geologists of the First Pennsylvania Survey (vol. II, part I, pp. 477, 492, 572 and 579). It is described by Rogers as a nodular limestone, in Western Pennsylvania, light blue or dove colored when freshly broken, but weathering yellow on account of the iron contained in it. The nodules are described as imbedded in clay, and as containing minute fossils.

In White's Report on Beaver county (Second Geol. Survey, Q, p. 47), the limestone is characterized as follows: "This member of the series, unlike its overlying coal, is quite persistent, and retains a somewhat uniform size and similarity of character over the entire district. It thus becomes a very important guide. Most generally it is of a light gray color on fresh fracture, but it nearly always contains enough iron to render it buffish on exposure, and sometimes even enough to constitute it a valuable ore. . . . It is nearly always more or less

brecciated, and often looks as though it was composed of the broken and worn debris of some other limestone. It is usually very hard and compact, and is never fossiliferous, the most careful search in hundreds of localities having failed to discover anything in the shape of fossils in it, except a minute univalve of almost microscopic proportions. The entire absence of organic remains from this limestone is a very singular feature when taken in connection with the fact that other limestones of the coal measures, both above and below it, are crowded with them, and it may well point to a marked difference in the condition of their deposition. This limestone may be of fresh water origin. . . . It contains so much earthy matter and other impurities that it is often very difficult to get it to slake, and hence it has rarely been burned. Its average thickness is about 3 feet."

The well-known Upper Freeport coal lies a few feet above it when the latter is present in the section. At about 40 feet below it is the place of the Lower Freeport coal, also an important seam. This coal also has a limestone, the Lower Freeport limestone, below it, and it agrees quite closely in general characters with the seam described above, except that it is very much less persistent. A heavy sandstone frequently underlies the Lower Freeport coal. It is the Freeport Sandstone of the First Survey, and the Lower Freeport Sandstone of the Second Survey. An ore seam of some local value is often found at about 15 feet below the Upper Freeport limestone. The interval between the two Freeport coals is also occupied by a sandstone in some cases, but generally it is filled with shale or clay. A bed of non-plastic fire-clay is quite a regular element in the series, the place of which is just below the Upper Freeport limestone. It is the Bolivar fire-clay of Indiana county, Pennsylvania.

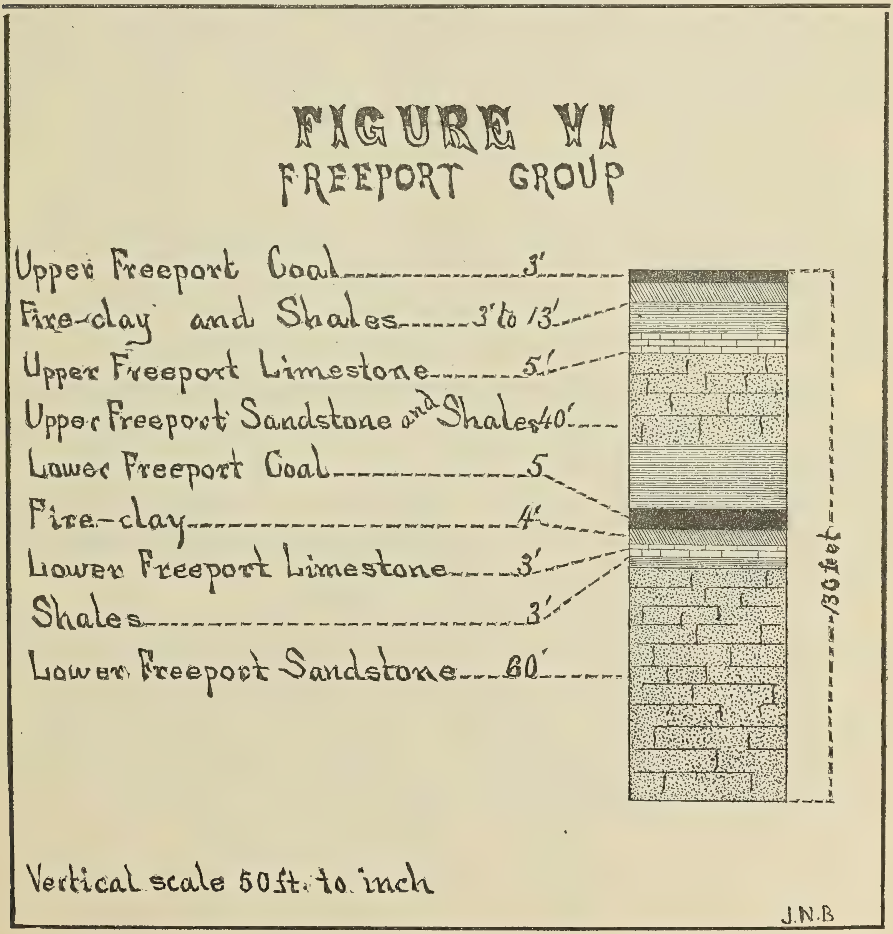
All of these elements have been recognized and described in Ohio Geology, though the continuity of the series has been sometimes lost in tracing it westward from Columbiana county.

The Upper Freeport limestone of Beaver county, Pennsylvania, extends without interruption into Columbiana county, Ohio. It was here recognized in its true character by Newberry, though he frequently uses the local name *White limestone* in speaking of it. Newberry also identified the same stratum in Green township, Mahoning county. It is certain that the Goodman Hill limestone of this locality is one of the Freeport limestones, but it may prove to be the lower of the two. The

Lower Freeport limestone has the same characteristics as the upper, and both are found in this portion of the State.

Westward and southward from these counties, the Freeport limestone, though everywhere present, and agreeing in all respects with the exposures in Eastern Ohio and Pennsylvania, has lost its proper name, and has received several local designations. It is one of the buff limestones so frequently referred to in Newberry's reports on Stark and Tuscarawas counties in connection with the black-band horizon. It is the buff limestone under the Cambridge and Alexander coals of Andrews's reports on Muskingum and Perry counties, and in the report on the Hanging Rock district, it figures as the Shawnee limestone. (Geol. of Ohio, vols. II and III.)

All of the elements associated with the limestone occur in Ohio in exactly the same order as in Pennsylvania, and can be followed with unmistakable distinctness entirely across the field.



These three limestones and the beds associated with them, as already described, constitute the most available guides to the order of the Lower Coal Measures. They all exist in normal development in Ohio, as has been already shown, and the only question as to their successful use turns on the possibility of identifying them with certainty in their varied and perhaps widely-separated exposures. Can any one of these limestones or any one set of the beds that have been grouped together, be clearly and positively distinguished from every other, or is there danger of confusing and confounding two or more distinct horizons? The answer to such questions is that the several elements and groups already named are so sharply distinguished and defined that no geologist who has at once an adequate knowledge of the coal measures in general, and of the particular district which he is examining, can be left in doubt as to any of these horizons wherever they are found in good development.

In the following diagram, Fig. VII, the usual relations of these several limestones to each other is indicated. The intervals given are those more commonly found in Northeastern Ohio, but it must be borne in mind that they expand rapidly towards the southeast.

The aim of the present chapter is to show a true order for the Lower Coal Measures of Ohio by the proper use of the leading and determinable elements to which attention has now been called, and by such other elements as shall be found adapted to the purpose.

Beginning on the eastern border of the State we find in Mahoning county a geological section that is in all respects common to Ohio and Pennsylvania. The Mahoning river flows out of Ohio into Pennsylvania, opening a deep valley into which numerous tributaries descend from the high lands on either side, disclosing almost every foot of the strata that they cut in their numerous sections.

The sections at and about Lowellville are clear and accessible, and they have been made to do geological service more than once. Newberry publishes a section from Lowellville as illustrative of the geology of the valley, in his report upon Mahoning county. (Geology of Ohio, vol. III, p. 804). White gives several sections from this vicinity in his report on Lawrence county and the Ohio line (Q 2, p. 219).

FIGURE VII

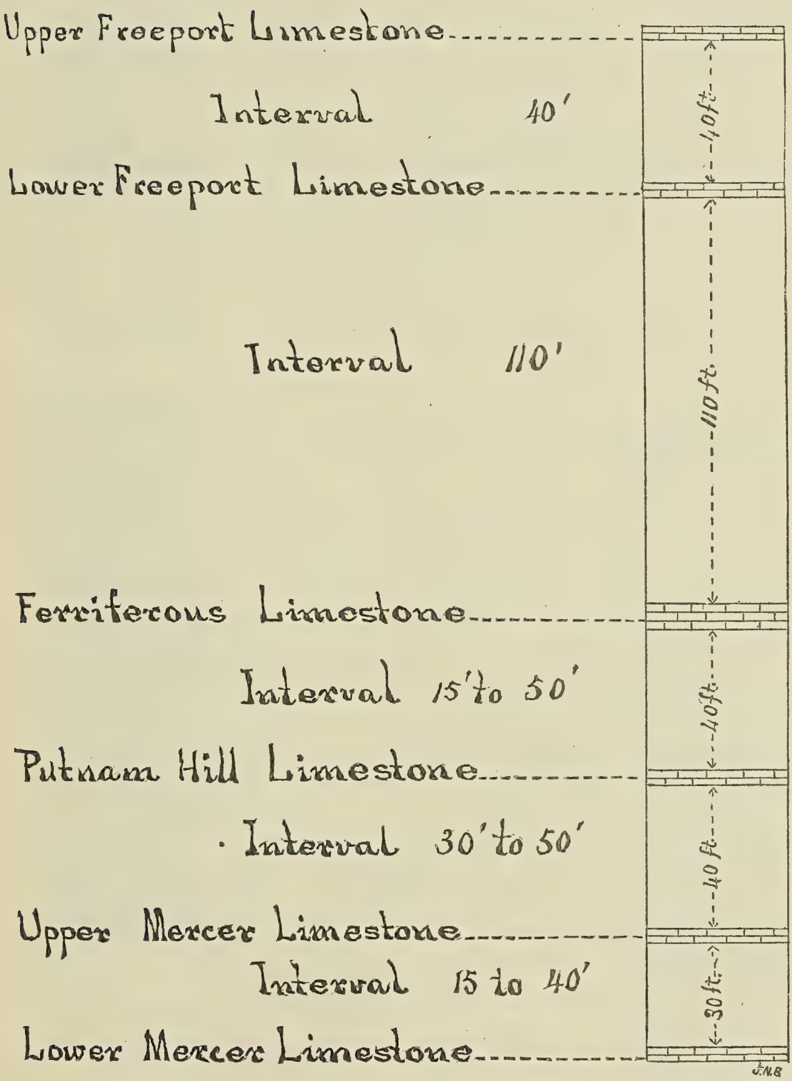
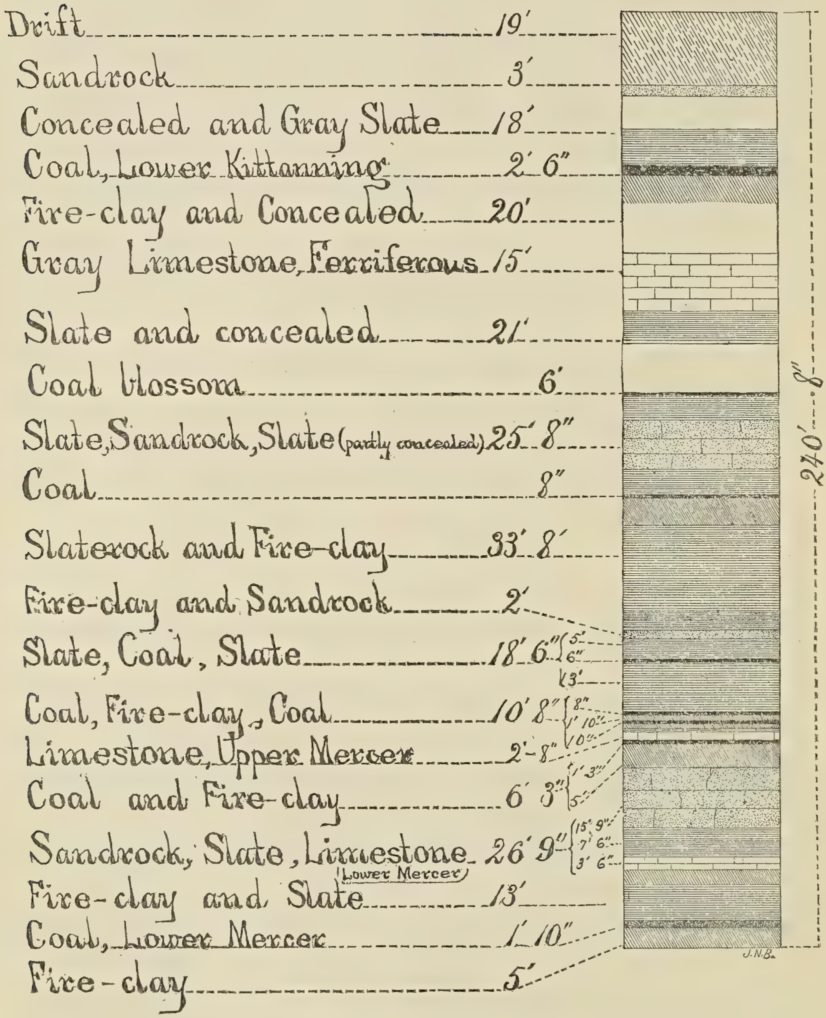

Upper Freeport Limestone
Interval 40′
40 ft.
Lower Freeport Limestone
Interval 110′
110 ft.
Ferriferous Limestone
Interval 15′ to 50′
40 ft.
Putnam Hill Limestone
Interval 30′ to 50′
40 ft.
Upper Mercer Limestone
Interval 15 to 40′
30 ft.
Lower Mercer Limestone
J.N.B

FIGURE VIII

GRINDSTONE HOLLOW SECTION, LOWELLVILLE



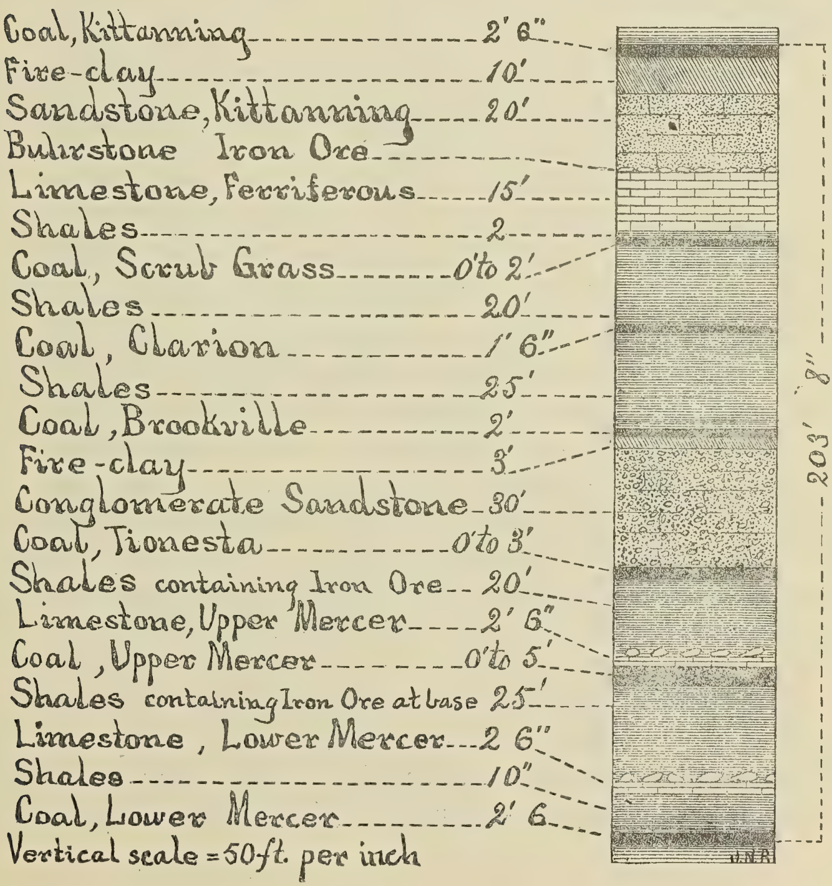
The above section, Fig. VIII, is taken from Grindstone Hollow, within ½ mile of Lowellville. It reaches to the summit of the hill on James S. Moore's farm. It accords with the sections named above in all essentials. Three of the strata that have been described in the previous pages as determinative of the sections in which they occur, are found here. They are the Lower Mercer limestone, the Upper Mercer

limestone, and the Ferriferous limestone. There are no open questions as to these identifications. The Lowellville upper limestone is the Ferriferous limestone of Pennsylvania, if there is any such stratum. White's connected sections give a complete demonstration of the points involved in this identification. (Report on Lawrence county and the Ohio line, Q 2, pp. 215 et seq.)

The two limestones next below have an equally clear title to the names by which they are respectively designated, the Upper and the Lower Mercer.

To interpret this section, there is placed by the side of it a section covering the same range, Fig. IX, combined from the two diagrams already introduced, to illustrate the geological order of Western Pennsylvania:

FIGURE IX



By a comparison of the Lowellville section with this general section, it will be seen that the coal 30 feet above the Ferriferous limestone is the Lower Kittanning of Pennsylvania (Kittanning of Rogers, Coal C of Lesley). The well-known Kittanning clay-bed appears beneath it. Under the Ferriferous limestone a small development of the Scrub-grass (Upper Clarion) coal is seen.

The Clarion (Lower) coal is wanting in the section, but the eight-inch coal, 50 feet below the limestone, will answer well for the Brookville coal (Coal No. 4, of Newberry, in Stark county). The distance to the limestone horizon is somewhat larger here than it is to the westward.

The thin seams of coal above the Upper Mercer limestone obviously represent the Tionesta coal. A seam ranging from $2\frac{1}{2}'$ to $4'$ in thickness is found within a short distance on the other side of the river at this horizon.

The Mercer coals show for themselves, and need no comment. These are coals 3 and *3a* of Newberry, in Stark county, and to the westward.

The horizons of the Quakertown and Sharon coals are reached lower down, but neither of these inconstant elements appears in the section. The ore-bearing shales that overlie the Sharon coal are, however, distinctly shown throughout this region, and have been worked for the ore to a considerable extent.

The distance between the Lower Mercer and the Ferriferous limestones in the Lowellville section is 143 feet, but this is in excess of the usual measure by 20 to 30 feet. The Lowellville measurement is in fact a maximum, while the same interval in adjacent sections, as shown by Newberry and White, is reduced to 105 or 110 feet. The average of 6 sections in the vicinity is 121′, and the usual measurements of this interval in Mahoning county will range between 105′ and 125′. The place of the Block coal is about the same distance below the Lower Mercer limestone that the Ferriferous limestone is above this stratum, so that the average distance of the Block coal in this region below the Ferriferous limestone is 250′. Its maximum would reach nearly 300 feet.

The outcrop of the Ferriferous limestone at Lowellville is the last one found in ascending the Mahoning Valley. None of the hills that border the valley above this point are high enough to reach its horizon, but the Mercer limestones continue in excellent and unmistakable de-

velopment. All the principal streams in Poland, Youngstown, Austintown, and Canfield disclose them either in the main valleys or in their tributaries wherever their horizons are reached. Newberry pronounces the Lower Blue limestone (Lower Mercer) "the most constant limestone bed in Mahoning county," and his sections and statements show its presence in all of the northern townships. (Geology of Ohio, vol. III, p. 794).

It is extensively quarried in Austintown and Canfield for furnace use, and its underlying coal, No. 3, of Newberry, for this district, has been mined for a number of years for shipment in the same towns.

An interesting section given by Newberry shows the Putnam Hill limestone coming distinctly into the Mahoning county series, to re-enforce these other well-known elements. A boring was made on the south line of Youngstown township, not far from Fosterville, which gives the following record (vol. III, p. 803):

		Feet.	Inches.
1.	Earth	23	9
2.	*Black shale*	5	6
3.	Sand-rock	12	
4.	Gray shale	17	6
5.	*Limestone*	2	7
6.	Brown shale	5	
7.	Gray sandy shale	31	5
8.	*Limestone*	3	9
9.	Gray shale	31	3
10.	*Limestone*	6	
11.	Reddish sandy shale	23	
12.	Brown shale	25	
13.	Gray sandy shale	30	
14.	Sand-rock	18	
15.	Gray shale	24	
16.	Black shale	1	6
17.	*Coal No.* 1 (Block coal)	5	

In this series, No. 10 undoubtedly stands for the Lower Mercer limestone. The interval between it and the Block coal is somewhat less than usual, but this measurement does not stand by itself. Newberry gives 100 to 150 feet as the range of this interval in the county, and a measurement of 125′ or thereabouts has already been named as the usual one. No. 8 of the section is by the same token the Upper Mercer limestone, while the third limestone, or No. 5 of the section,

holds the proper place for the *Putnam Hill Limestone,* and marks the easternmost point to which it has been distinctly traced. The black shale, No. 2, which is the first bedded rock found in the drill-hole, is 107 feet above the Lower Mercer limestone, and probably finds its place at or near the horizon of the Ferriferous limestone. A bed of black slate is the most common representative of this horizon when the limestone itself is wanting. The Upper Clarion coal also belongs in the same neighborhood and might show as a black slate here.

The various outcrops of the strata in the townships of Canfield and Green furnish, however, the best section of this portion of the field.

Ascending Mill Creek from Youngstown and its chief tributary, Indian Creek, from near the center of Boardman township, we pass successively over the horizons of the Sharon Conglomerate, the Sharon coal, the Massillon or Connoquenessing sandstone, until in the southwest corner of section 22, Canfield, on the farm of D. Heintzelman, we find the Lower Mercer limestone, with its coal and ore, lying at the drainage level. The exposure is clear and unambiguous. The Upper Mercer coal has been worked for local supply immediately above it, and the interval is found to be the usual one, 35 feet.

The Upper Mercer coal is also worked on the adjoining farm of Wm. J. Swanston, section 21, and here a measurement is obtained to the Canfield Cannel seam which has been opened and worked on a small scale. The seam can be followed with perfect distinctness to this point from the farms where it has been most largely worked.

The cannel seam lies 85 feet above the Upper Mercer coal, and 120′ above the Lower Mercer limestone.

The cannel seam has been traced and proved through all the central portions of Canfield township, and a section similar in all respects to the one already given, can be obtained by following up the Meander Creek and its tributaries on the northwestern side of the town.

The Lower Mercer limestone and its coal and ore are found in fine development in this part of the township. The limestone has been quarried for shipment to the Leetonia furnaces on sections 3 and 4, and on the same sections, Wick and McDowell have mined, for the general market, the Lower Mercer coal.

On section 6 the Upper Mercer coal is worked quite extensively to meet a local demand. It is known as the Bruce or Kirkpatrick coal in this part of the township. It is overlain by its limestone in many in-

stances. The seam is identified by Newberry at all of the points, named as Coal No. $3a$ of his scale. The cannel seam may be the next one found in this immediate vicinity above the Upper Mercer coal, but it is certainly not the next in the series. This is the most prolific portion of the Lower Coal Measures, and we cannot find in any part of it an interval of 85′, nor of even half that distance from any coal seam to the next one, that is *due* above it. The measurement already given shows approximately the place of the Canfield cannel in the series. *It belongs to the horizon of the Ferriferous limestone.* Other facts will presently be brought forward establishing this conclusion, but it is to be distinctly noted that it is not No. 4 of the Stark county series. That coal seam belongs to the horizon of the Putnam Hill limestone, which lies from 30′ to 50′ below the cannel coal.

The cannel seam can be traced without difficulty into section 30, in the southwestern corner of the town. It has there been mined for local supply for a number of years on the farm of John Ewing, but it is no longer cannel. It consists here of two feet of bituminous coal, overlain with six inches of cannel.

Two coal seams are found at this horizon, on the Ewing farm, a peculiarity which greatly aids in tracing and identifying the horizon to the southward. Below the cannel and separated from it by a bed of fire-clay, a lower seam appears. The interval at Ewing's is 8′. The lower seam is reported to be between 2′ and 3′ thick. Fragments of blue fossiliferous limestone are seen where the earth has been moved to reach the cannel, but the exact relation of the limestone to the coals could not be determined here. Only the upper coal is worked at this point, and this in a small and irregular way.

The White limestone of Nicholas Goodman's hill, Green township, is but a mile from the Ewing coal, and the section already obtained was extended by measuring the interval between these two well-known horizons. The level gave 135′ for this interval, but as the measurement was made in the direction of the dip, it will be necessary to add 15′ to 20′ on this account. The White limestone is thus seen to be 150 feet above the Ferriferous horizon, 270′ above the Lower Mercer limestone, and approximately 400 feet above the Block coal.

The limestone belongs unmistakably to the Freeport group, as Newberry has shown. It is a buff-colored, earthy, nodular, brecciated non-fossiliferous limestone, passing into an impure and worthless iron-

ore by scarcely-marked gradations. It lies in two distinct benches, that are separated by about 5′ of fire-clay. It may prove to be the Upper Freeport limestone, but the double structure and the measurements correspond better with the Lower Freeport limestone. Both aie found throughout the district to the southward, and in their ordinary phases are as hard to distinguish from each other as the Mercer limestones are.

A heavy sandstone is found covering the Canfield cannel seam in almost all of the drill-holes. Few opportunities are found for examining this stratum by outcrops, on account of the drift beds which cover and obscure the surface. It is probable that the lower portion of this deposit is the Kittanning sandstone, a steady stratum in Pennsylvania that separates in part the Lower Kittanning coal from the Ferriferous limestone, but from the drill records it would seem that a higher sandstone, the Lower Freeport, presumably, has cut away all intermediate beds, and for a limited area has dropped down directly upon the lower sandstone, thus making a stratum of greater thickness than any one bed would warrant, and obliterating an important part of the record. The absence of the Kittanning coal from the Canfield sections seems to require such an explanation. It is well developed in the adjoining township of Green, and has been mined very largely there for a number of years.

At Cook's crossing, on the Niles and New Lisbon Railroad, in section 11, Green township, on the farm of J. M. Pettit, and in the valley of the Cherry Fork of Little Beaver, the Canfield cannel seam has been quite extensively worked. As in the last instance, it is no longer a cannel, except for a few inches at the top of the seam. The same duplication of the seam that was described on the Ewing farm is also found here. The interval from the main coal to the lower seam is less than before, only about one foot of clay being found at this point. The lower coal is worthless. The Pettit coal has been identified as the Canfield cannel seam, by means of the numerous holes that have been drilled to prove the extent and character of this seam, and all of the facts match to this view.

The coal lies 29 feet below the railroad track, at the foot of the old shaft, but its floor is very uneven, and there is said to be a difference of 20 feet in the mine between the swamps and the hills.

A mile and a half south of this mine, at Green Station, the Lower Kittanning coal makes its first appearance. This is Coal No. 5 of New-

berry, in Tuscarawas and Stark counties, as will presently be shown. It has been mined here by Andrew Reichstadt on section 23. It lies 15 feet above the railroad, or about 40 feet higher than the Canfield seam at Cook's Crossing. At this point the Kittanning coal has a structure quite similar to that of the Ewing and the Pettit coal, last described. There are 2½ feet of bituminous coal, overlain with 4 to 6 inches of cannel. This agreement in structure has led many to consider the Reichstadt coal to be the same seam as the Canfield cannel, but the facts do not sustain this view.

The Kittanning coal can be followed from Green Station to the southward along the valley of the Cherry Fork, without difficulty. It falls a little faster than the valley, so that at the Walters Mine, section 35, Green township, it lies about level with the railroad. According to the view adopted in this report, the Canfield cannel seam, if present, should be found about 40 feet below the Walters coal. The seam is present, has been reached by a shaft at a depth of somewhat more than 40 feet, and has been mined in connection with the Kittanning coal above it. The section between the coals is as follows, according to the record of Mr. John Walters, who sunk the shaft:

Fire-clay	7 feet.
Gray shale	13 "
Dark shale	18 "
Chip slate, fossiliferous / *Calcareous nodules* / *Cone-in-cone*	4 "
Coal	3½ "
Clay	2 "
Coal (not mined)	1 foot.

This section is very instructive. It not only discloses the Canfield seam in its proper place, but it also serves to establish the identity of this seam with the Ferriferous limestone horizon. It will be remembered that the concretionary structure, "cone-in-cone", is a constant mark of the Ferriferous limestone horizon, whenever the limestone grows thin. The heavy bed of clay under the Kittanning coal is also characteristic. In fact the whole section is in all respects normal.

Two feet below the lower coal, and separated from it by fire-clay, the same worthless seam that comes in to the northward is found, completing the demonstration of identity.

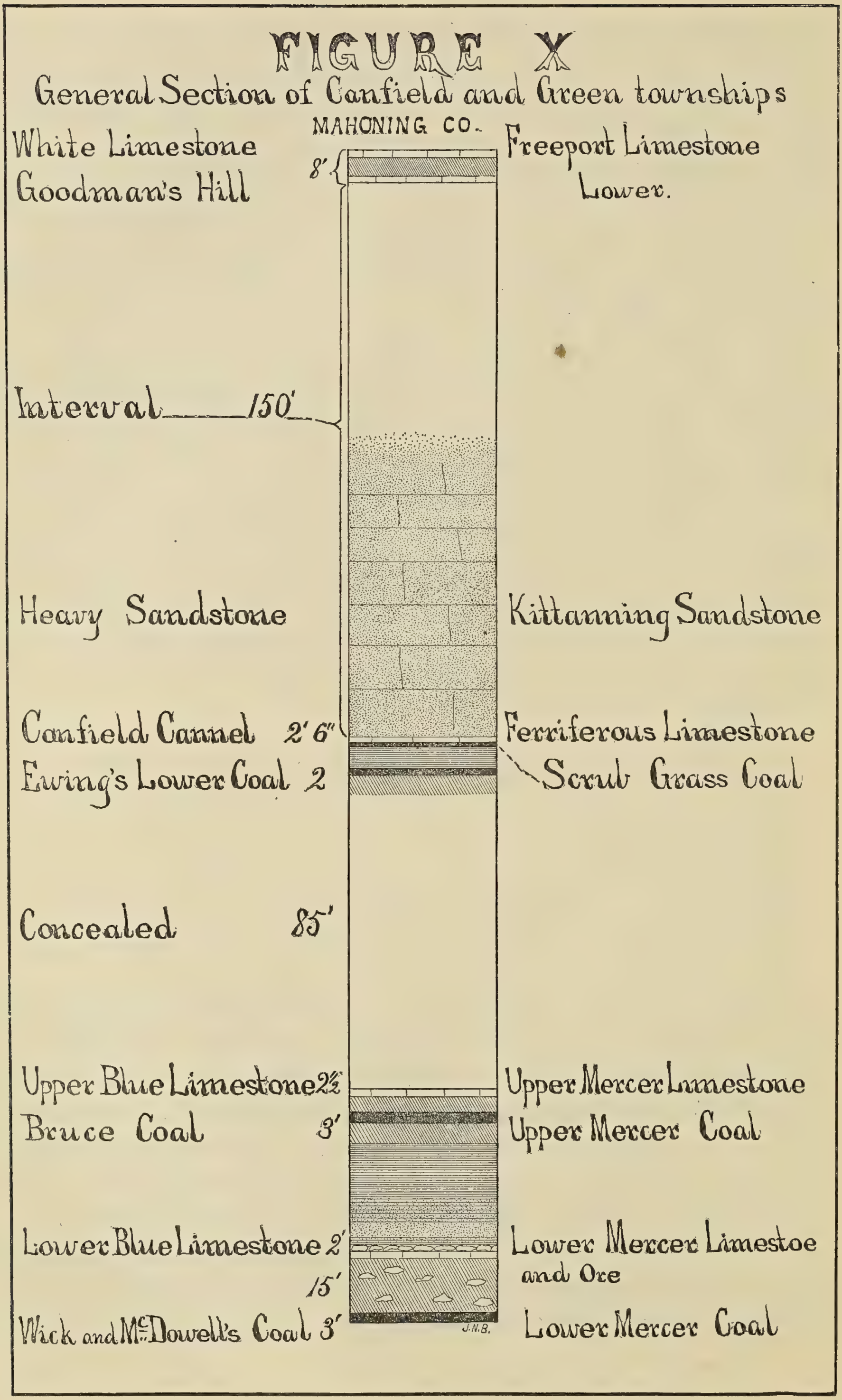


FIGURE X
General Section of Canfield and Green townships
MAHONING CO.
White Limestone
Goodman's Hill
8'
Freeport Limestone
Lower.
Interval 150'
Heavy Sandstone
Kittanning Sandstone
Canfield Cannel 2' 6"
Ferriferous Limestone
Ewing's Lower Coal 2
Scrub Grass Coal
Concealed 85'
Upper Blue Limestone 2½
Upper Mercer Limestone
Bruce Coal 3'
Upper Mercer Coal
Lower Blue Limestone 2'
Lower Mercer Limestoe
and Ore
15'
Wick and McDowell's Coal 3'
Lower Mercer Coal
J.N.B.

At Washingtonville and Leetonia the Kittanning coal has been worked for a long time and in the large way. It is a coking coal of great excellence, and the furnace fuel manufactured from it is not excelled in the State.

By those who have counted the Leetonia coal the equivalent of the Canfield cannel, the same number has been placed upon it that the latter seam is made to bear, but "Coal No. 4," at Leetonia, is entirely distinct from the other two seams to which this number has also been given.

Counting the Leetonia coal as the Lower Kittanning seam, and supposing the series south of the Canfield divide to agree substantially with the series north of the divide, which has already been represented in section, a shaft sunk at Leetonia ought to cut the following strata in the general order named below:

At 45 feet below the Leetonia coal, the Canfield cannel seam should be found. At 125 feet the horizon of the Upper Mercer group should be reached, and the Lower Mercer horizon at 160 feet. If the Gray or Putnam Hill limestone were to occur, its place would be 80 to 90 feet below the Leetonia coal.

A number of holes have been drilled at Leetonia by the furnace companies, and the records have been kept with care. From the registers of six of these holes, one is selected that fairly represents them all.

The record of Drill-hole No. 1, on the Grafton Furnace property is as follows, no change being made in the transcript, except to point out the place of the Leetonia seam:

		Feet.
1.	To sand-rock	37.00
2.	To gray slate	87.03
3.	To FIRST COAL SPACE (Leetonia seam, 2′ 4″)	100.00
4.	To limestone ore	102.04
5.	To gray slate	104.00
6.	To iron ore	116.40
7.	To gray slate, light	116.10
8.	To gray slate, dark	127.00
9.	To SECOND COAL SPACE (3′)	147.60
10.	To fire-clay	150.60
11.	To soap-stone slate	165.00
12.	To dark clay	171.60
13.	To THIRD COAL SPACE (3′ 4″)	175.40
14.	To gray slate rock	178.80

		Feet.
15.	To Gray Lime	·190.20
16.	To gray slate	191.60
17.	To chip black slate	195.60
18.	To gray slate, dark	200.00
19.	To gray slate, very dark	214.00
20.	To Fourth Coal Space (7″)	222.30
21.	To fire-clay	222.10
22.	To gray slate	227.60
23.	To fire-clay rock	247.60
24.	To gray slate, dark	248.00
25.	To Fifth Coal Space (1′ 7″)	253.10
26.	To fire-clay	255.50
27.	To dark slate	257.50
28.	To conglomerate	259.20
29.	To bottom	259.80

Reducing this section to the proposed basis, by counting downward from the Kittanning coal, we find the following order shown:

At 47 feet below the Leetonia coal, a coal seam 3′ thick occurs; at 75 feet, another seam 3′ 4″ thick; at 90 feet, a *Gray Limestone;* at 122 feet a fourth coal is found, 7″ thick, and a fifth seam, 19″ in thickness, at 154 feet below the Leetonia seam. A blue limestone, 16″ thick, is reported in one of the drillings, a little above the level of the fifth coal.

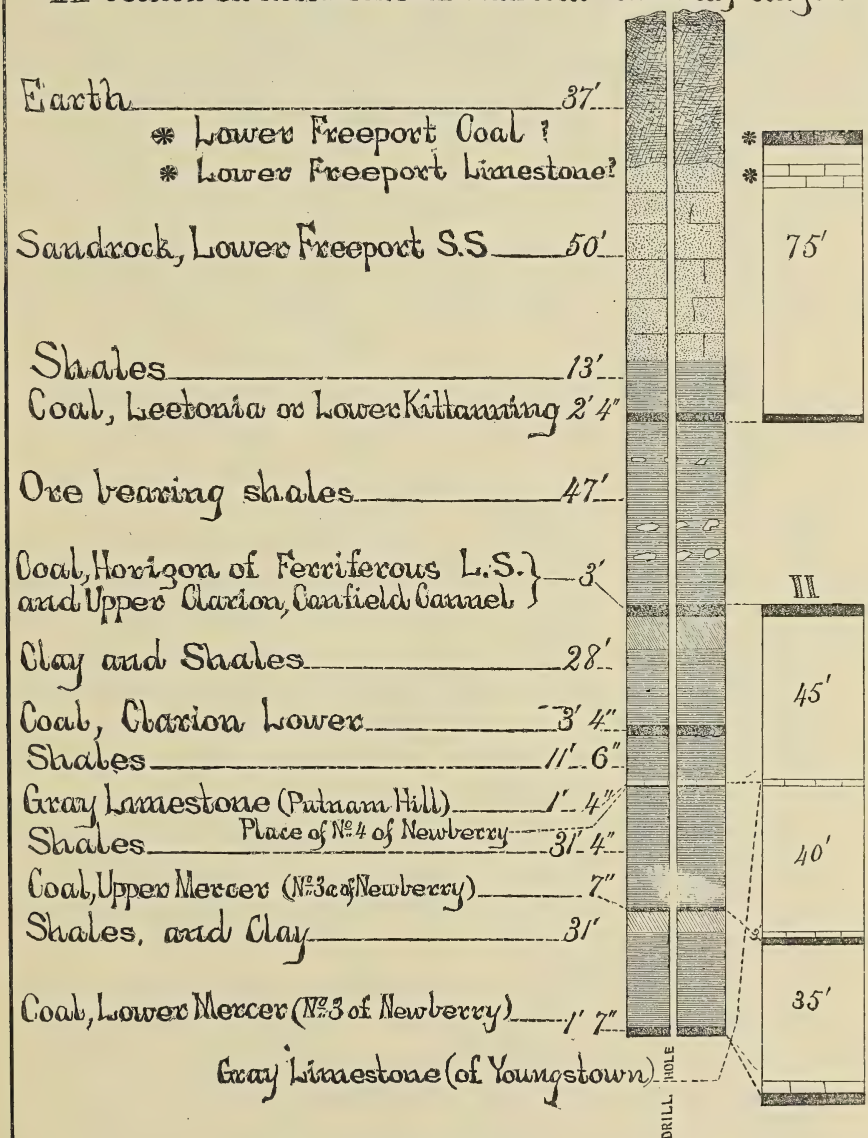
The gray limestone, which is found at 90 feet below the Kittanning coal, is a very interesting, and by no means an unknown element. It appears in 3 out of the 6 holes that were drilled at Leetonia, at distances of 85′, 90′ and 91′ below the Leetonia coal, or of 62′, 64′ and 69′ above the Lower Mercer coal. Holding the exact position of a well-known and conspicuous element in the northern counties of the coal field, there seems little reason to doubt that in the "gray limestone" of the drill record, the long buried Putnam Hill limestone, has again been brought to view. A thickness of 16 inches is reported in one of the records.

The coal seam that is found 47 feet below the Leetonia coal, appears in every record, with a thickness ranging from 3′ to 3′ 3″, except in one hole, where but 6″ is reported. The distance of this seam below the Leetonia coal, in the several holes, is as follows: 36′, 43′, 47′, 47′, 47′, 55′.

The coal seam shown in No. 13 of the section, occurs in five out of the six holes reported. Its thickness ranges as follows: 1′ 2″, 2′ 10″, 3′ 3″, 3′ 4″. Its distance below the Leetonia coal is shown in the fol-

FIGURE XI

Section at Leetonia as shown by record of Drill Hole №1, Grafton Furnace Company.
II. Section on north side of Canfield dividing ridge.



lowing figures, viz.: 58′, 73′, 74,′ 75′, 75′, 79′. Its distance below the seam next above it ranges thus: 11′, 20′, 27′, 28′, 33′, 38′.

The leading facts of the section are represented in the accompanying diagram, Fig. XI. By the side of it, the section which was obtained north of the Canfield water shed, and which has been already described, is shown. These sections are interpreted by the naming of their elements, in accordance with the views here presented, but it is hard to see what other interpretation of the principal facts is possible, for it must be borne in mind that the Canfield cannel seam is common to the two sections, having been traced completely through the dividing ridge from north to south, as all agree.

To complete the statements as to the proper place of the Canfield cannel, the elevations of the seam above Lake Erie are here given for three of the points named. The coal is by a close approximation:

At Canfield Station	595′ above Lake Erie.		
At Cook's Crossing (4½ miles below)	529′	"	"
At Walters Mine (7½ miles below)	451′	"	"

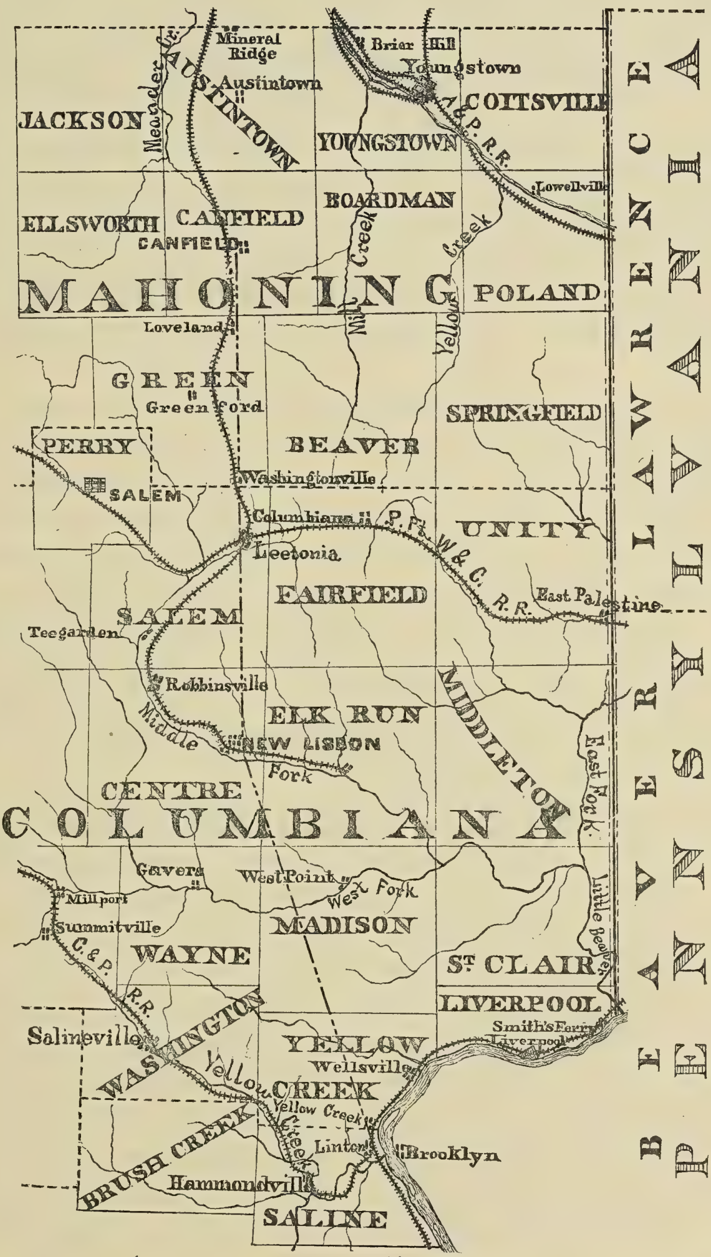
The dip increases somewhat to the southward, but its general course is unbroken. On the theory that the Leetonia coal is the Canfield cannel, it has been found necessary to introduce a reverse dip at Green Station, but there is nothing to indicate any such irregularity, and nothing to suggest it, except the necessity imposed by a wrong identification.

Some of the borings at Leetonia were undertaken in a search for the Block coal, but only one was carried deep enough to reach its horizon, and this fell short of the normal measure. There seems but little reason to expect the Block coal so far away from the boundary of the coal field, but the borings made do not demonstrate its absence from this part of the field, the lowest reaching but 105 feet below the Lower Mercer horizon.

The Lower Freeport limestone and coal are found at Leetonia, at a height of 75 feet above the Lower Kittanning coal. The interval is shorter than it is to the southward, but it agrees with the ordinary measurements in the upper valley of the Little Beaver.

The facts already given afford the true interpretation of the Leetonia section, but the interpretation now presented does not rest on these facts alone.

SKETCH MAP OF MAHONING AND COLUMBIANA COUNTIES.



Line of section shown in Fig. XIV

The two seams with which we have been chiefly occupied, viz., the Leetonia and the Canfield cannel seams, can be followed further down the valley. The latter seam is brought once more to day in the deep valley of the Middle Fork, at New Lisbon, and for several miles above. The westward trend of the valley also contributes to its restoration to the sections here. The Leetonia coal can be traced from point to point with perfect distinctness, but it becomes temporarily thinner to the southwest, and in the vicinity of New Lisbon it is no longer mineable. The interval between the coals remains the same as to the northward, viz., about 40 feet. At New Lisbon, the Canfield seam has regained its normal cover, viz., the Ferriferous limestone. This stratum is found here, blue and impure, but crowded with its characteristic fossils. The "cone-in-cone" formation accompanies it, and also the highly fossiliferous black slate that often replaces the limestone.

These two seams, the Canfield cannel and the Leetonia coal, are the seams called No. 3 and No. 4 by Newberry in his New Lisbon sections (vol. III, p. 107). From the Leetonia sections it is apparent that the Lower Mercer coal must lie at least 125 feet below the bed of the Middle Fork, the Ferriferous limestone being found here near the water level. As the intervals generally expand to the southward, a larger measure would seem probable. In the borings mentioned by Newberry, as made near Elkton by Mr. H. C. Bowman, two thin coal seams were reported at 129 feet and 150 feet, respectively, below the creek bed (vol. III, p. 110). There seems some reason to count these seams as the Upper and Lower Mercer coals.

But in the region which we have now reached, we are no longer confined to the Ferriferous limestone and the Kittanning coal for our guides. Another, and an equally characteristic series of beds of coal and limestone has come in above them, and extends in easily traced and universally recognized continuity to the Pennsylvania line and beyond. The Freeport group attains a full development throughout eastern and southern Columbiana county. Its coals and its limestones and the two great sandrocks that enclose the system, the Mahoning sandstone above, and the Lower Freeport sandstone below, constitute so important and striking a portion of all the sections in which they are found, that they can neither be overlooked nor misinterpreted. Consequently there are no differences of opinion as to the presence or elements

or exact position of the Freeport Group in eastern Columbiana county. There are only four coal seams of the Ohio scale about the equivalents of which in Pennsylvania no question is raised. These seams are the Block coal of the Mahoning valley, which is the Sharon coal of Pennsylvania, coals Nos. 5 and 6 in eastern Columbiana county, which are the lower and upper Freeport coals, respectively, of the Pennsylvania series, and finally the continuity of the Pittsburgh seam through both states is unchallenged.

The extensions of all of the other seams of the Coal Measures can also be followed visibly and bodily from the one state to the other, but names and places have in many cases been assigned to them before they were carefully followed, and great confusion has resulted therefrom.

Fortunately the Freeport Group comes into the same sections that hold the Kittanning coal and the Ferriferous limestone at their bases, and we can avail ourselves of the guidance of both series as we advance.

The sections at and about New Lisbon are clear and full, and the whole series that is shown here can be followed down the valleys of the Middle Fork and the Little Beaver into the Ohio valley, where it is connected directly with the well established system of the Lower Coal Measures of Pennsylvania.

A few sections are selected that fairly represent the district from New Lisbon to the Ohio River.

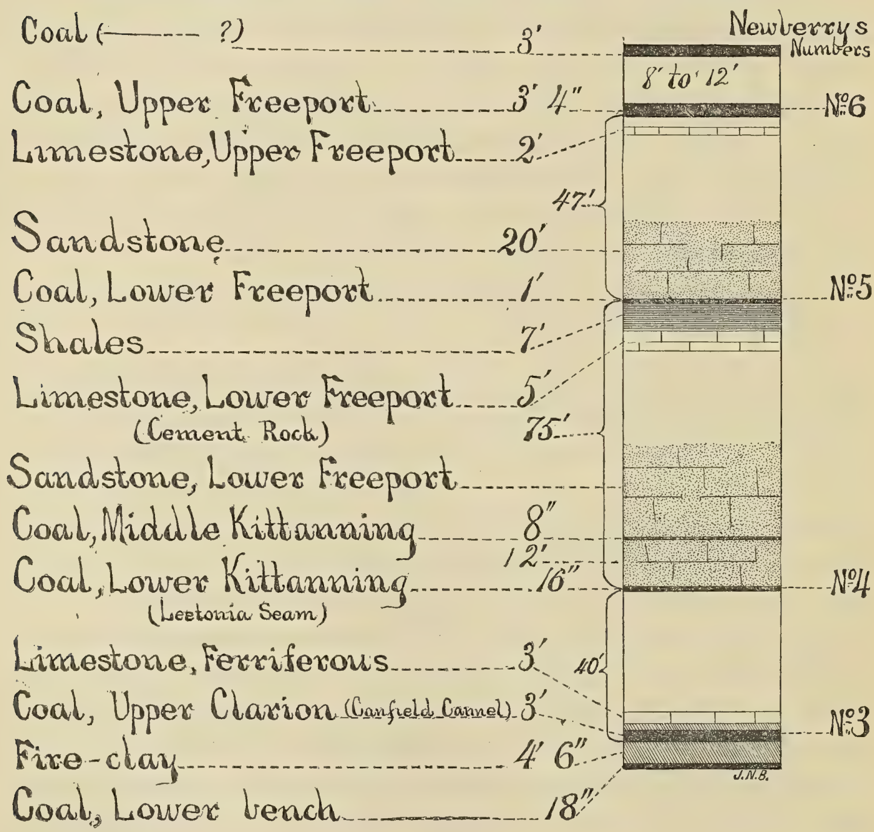
Three miles above New Lisbon, the Niles Mining Company is working the coal immediately below the Ferriferous limestone (the Upper Clarion). The seam is double here as usual, a thin bed underlying the fire-clay of the main seam. Forty feet above this coal, the Leetonia seam is found, but it is here reduced to 16″ in thickness. Fifteen feet above the Leetonia coal, another thin coal occurs. It is here but 8″ thick, but it makes an element of great value in Ohio Geology. It is the upper Kittanning of White and the middle Kittanning of Chance. It will presently be found to become a constant and important feature in all our sections. Passing down the valley to the Cement Works, we are able to add some higher beds to the section. On McGowan's Hill, we find the Lower Freeport limestone extensively worked as a cement rock. It lies 68 feet higher than the Leetonia coal. Seven feet above the limestone, or 75 feet above the Leetonia coal, the Lower Freeport coal is shown in a bed, 8″ to 12″ thick. In the immediate neighborhood, the Upper Freeport limestone is found at 50 feet above the cement

rock, and the Upper Freeport coal is mined extensively at Armstrong's on the railroad. Above the Armstrong coal (No. 6 of Newberry) another seam is found, 3 feet in thickness, and of good quality, but under too light cover to be worked to advantage. The interval is not more than 12 feet at this place, and probably less. Being the next seam above No. 6 in this neighborhood, it is designated coal No. 7, but it is scarcely probable that it is the equivalent of the Brush Creek coal of Pennsylvania, which is the true extension of Newberry's No. 7.

These facts are represented in Fig. XII.

FIGURE XII

SECTION IN VICINITY OF NEW LISBON



Newberry gives a section taken from the same vicinity that show the same order and intervals. (Geol. of Ohio, vol. III, p. 108.) The

section was taken near the sandstone quarries one mile above New Lisbon. It is as follows:

White Limestone	4′
Shale	6′
Coal—local	1′
Shale	30′
Sandstone	50′
Dark Shale	35′
Iron Ore	0′ 8″
Coal No. 4	0′ 8″
Dark Shale	30′
Limestone	3′
Coal No. 3	3′
Fire Clay	5–8′

The interval from the Upper Clarion coal to the Upper Freeport limestone in this section is 159′. In the section previously given, the same interval is 162′.

The Lower Freeport coal becomes a valuable seam for a small area below New Lisbon, where it is known as the Whan coal. It here reaches a thickness of 4 to 5 feet. From this point to the Ohio river it is found in all of the hills, generally as a bituminous coal of 2′ or less in thickness, but often as a mass of bituminous shales, 6′ or 8′ in thickness. Newberry notes this fact, and he also remarks upon the great steadiness of the white limestone and its overlying coal (Upper Freeport) between New Lisbon and the Ohio river. (Geol. of Ohio, vol. III, p. 110.

The intervals between several of the elements expand rather rapidly to the eastward, and the whole section has gained from 50 to 75 feet before the valley of Little Beaver is reached. Along the sides of this deep furrow, frequent exposures of all the leading elements are found.

The true interpretation of the long sections furnished here, aside from the recognition of the Freeport Group, which seems never to have been misunderstood, was first given by White, in his report on the Ohio line (Q 2, p. 263, et al.) By a series of closely connected sections he followed both the Freeport and the Kittanning groups, the latter including also the Ferriferous limestone, from their typical and full development in Pennsylvania to the mouth of the Little Beaver, and thence up this valley for miles of fairly consecutive outcrop. A few of his sections will be repeated here to show the uniformity and reliable character of the leading strata.

At Fredericktown, where the Middle Fork unites with the Little Beaver, he finds the following section (Q 2, p. 272):

1.	Mahoning Sandstone—massive, pebbly	35′
2.	Shales and fire-clay	5′
3.	Freeport Upper Limestone (White Limestone).	3′
4.	Ochery Shales	40′
5.	Bituminous Shales (Freeport Lower Coal)	10′ to 15′
6.	Outcrops of massive sandstone	100′
7.	Ore bearing Shales—dark	10′
8.	Kittanning Coal	2′ 6″

(From Kittanning Coal to horizon of Upper Freeport Coal, 170′.)

One and a quarter miles above Fredericktown, a still clearer section was found. (Q 2, p. 274.)

1.	Mahoning Sandstone—massive	30′
2.	Fire-clay	3′
3.	Freeport Upper Limestone	2′
4.	Shales, sandy	45′
5.	Freeport Lower Coal { Bituminous Shale 10′; Coal 8″ }	10′ 8″
6.	Freeport Sandstone	85′
7.	Concealed	10′
8.	Kittanning Coal, smut	3′
9.	Fire-clay	10′
10.	Sandstone and Sandy Shales	55′
11.	Ferriferous Limestone, represented by dark, calcareous shale filled with fossils	5′

(From Ferriferous Limestone to horizon of Upper Freeport Coal, 225 feet. From Kittanning Coal to Upper Freeport, 155 feet.)

Another section was obtained 5 miles below Fredericktown, and $2\frac{1}{2}$ miles from the Ohio (Q 2, p. 266.)

1.	Mahoning Sandstone—massive, conglomeritic.	
2.	Freeport Upper Coal—irregular.	
3.	Freeport Upper Limestone and Fire-clay	2′
4.	Shales, sandy, dark	35′
5.	Bituminous Shale	10′
6.	Lower Freeport Coal	1′
7.	Fire-clay and Shale—sandy	6′
8.	Freeport Lower Limestone	3′
9.	Freeport Sandstone and sandy Shales	70′
10.	Shales, dark, with plants	5′
11.	Darlington (Middle Kittanning) Coal	1′ 6″
12.	Concealed	25′
13.	Kittanning Coal	2′

(From Kittanning Coal to Upper Freeport Coal, 160 feet.)

An important section is found at the mouth of the Little Beaver (Q 2, p. 263.)

1.	Mahoning Sandstone	30′
2.	Concealed	10′
3.	Shales, sandy	35′
4.	Ore bearing shales, dark, bituminous	3′
5.	Freeport Lower Coal, thin, impure	0′ 10″
6.	Shales, sandy	20′
7.	Freeport Sandstone—massive	50′
8.	Shales, sandy	15′
9.	Coal—local	1′
10.	Shales, sandy	20′
11.	Darlington Coal	2′
12.	Fire-clay	5′
13.	Ore bearing shales, dark	15′
14.	Kittanning Coal	2′ 6″
15.	Fire-clay	10′
16.	Shales and Sandstone	50′
17.	Ferriferous Limestone, impure, earthy and fossiliferous	1′

The Darlington coal No. 11, is the Middle Kittanning of some of the Pennsylvania geologists, and the coal, No. 9 of the section, is the Upper Kittanning.

To make sure that we have in this 1 foot of earthy limestone, the true representative of the Ferriferous limestone, we need one more section. It is found at Industry, in the Ohio valley, 5 miles above the mouth of the Little Beaver. (Q 2, p. 260.)

1.	Mahoning Sandstone—massive	70′
2.	Shales	5′
3.	Upper Freeport Coal	3′
4.	Shales and Sandstone	60′
5.	Concealed	10′
6.	Freeport Sandstone—massive	109′
7.	Darlington Coal	1′ 6″
8.	Shales	30′
9.	Kittanning Coal	3′
10.	Fire-clay	8′
11.	Sandstone—somewhat massive	50′
12.	Buhrstone Iron Ore	0′ 6″
13.	Ferriferous Limestone	15′

(From Ferriferous Limestone to Upper Freeport Coal, 278 feet. From Kittanning Coal to same, 204 feet.)

We find here the Ferriferous limestone in full force and with all the characteristic and valuable qualities of the stratum. The Kittanning sandstone has become much thicker than it was in our more northern sections, and the interval between the limestone and the Lower Kittanning coal is increased in this way, but the two Kittanning coals (Kittanning and Darlington of the section) serve to hold the section steady. Both are universally known and are opened on almost every farm. The Kittanning coal is known chiefly in connection with the great bed of fire-clay that it covers. It is termed on this account, the "Potters' Vein," and also by reason of its impure quality, the "Sulphur Vein". The middle Kittanning or Darlington coal is a thin seam, but it is everywhere esteemed on account of its excellent quality. It is known as the "Block Coal" through the valley.

In connection with the last section, an observation of White's is well worth repeating here. He says: "The sudden and rapid variations which the Ferriferous limestone often undergoes are here well illustrated. At the quarry, we see it 15 feet thick, only a few thin partings of shale separating the different layers. As we follow it along the steep bluff of the river, all the time perfectly exposed, we see the layers become arenaceous and shaly. In 400 yards it has entirely disappeared, except an impure layer at the top, 6 inches thick, exhibiting the "cone-in-cone" structure. There can be no mistake about the change, for the exposure is perfect between the two points, and the limestone is *seen* graduating into, and being replaced by sandy shales." (Q 2, p. 262).

The sudden disappearance of the Ferriferous limestone has always been a source of perplexity to those who have had to do with this stratum and with its horizon where the limestone has disappeared, and while the instructive example just quoted does not enable us to account for the surprising change, it is certainly a great advantage to find one section adequately laid open in which the change is accomplished. It is more important to learn how the horizon of the limestone can be followed after the limestone has disappeared. For the sagacious observations that have taught us this secret, we are indebted to the work of White in Beaver and Lawrence counties. (Reports Q and Q 2.)

Since leaving the valley of the Middle Fork, we have found but little coal associated with the Ferriferous limestone (Upper Clarion), while the thin seam first recognized above the Leetonia coal at New Lisbon has been developed into a regular and important seam, which

appears in all of our later sections as the Darlington or Middle Kittanning coal. The Lower Kittanning coal (Leetonia seam) is seldom missed from the sections, but its thickness generally falls below 3 feet throughout the Little Beaver valley. These two coals, the Lower and Middle Kittanning, hold, in the Ohio valley, about the same relations to each other that the Upper Clarion and Lower Kittanning hold at New Lisbon. The numbers by which these two coals are designated at New Lisbon, 3 and 4, have accordingly been shifted to the Lower and Middle Kittanning in the Ohio valley. The first of these numbers, 3, has been raised from the Lower Mercer horizon to the Lower Kittanning coal, resting temporarily at Leetonia on the Upper Clarion. The second number, 4, has been made to do more varied service. Originally fixed upon the upper limestone coal (Gray or Putnam Hill), we find it next assigned to the Canfield Cannel (Upper Clarion, which has no regular number in the Ohio classification). When this seam emerges from the Canfield dividing ridge as it is followed southward, its old number, 4, is given to the Lower Kittanning that now comes into the section, and it is for a time known as No. 3. A similar slipping upward of the numbers takes place once more in the valley of the Little Beaver, as has been already shown where the Lower Kittanning becomes coal No. 3 and the Middle Kittanning becomes No. 4.

Coming down the Ohio Valley from the mouth of the Little Beaver, we hold the section found there unbroken and unchanged to the mouth of Yellow Creek and beyond. That the "Clay Vein coal" or "Sulphur Vein" of Smith's Ferry and above, is the "Clay Vein," "Potters' Vein" and "Sulphur Vein" of East Liverpool and Wellsville, and the "Creek Vein" and "Potters' Vein" of Yellow Creek and Linton, is called in question by no one. The openings to the claybed are so closely connected, and in some parts of the field so nearly continuous, and the entire section of the elements involved is so thoroughly characteristic, that though the levels of the beds are sometimes changed by the low anticlinal axes or folds that pass through this portion of the State, the identity of the beds is never shaken nor invalidated. That the Clay Vein coal of Smith's Ferry is the Lower Kittanning coal of Western Pennsylvania is as well settled as any fact in the geology of the Upper Ohio Valley. The extension of the Pittsburgh coal into Ohio is in no wise more certainly determined than that of the Lower Kittanning coal. The identity of the "Creek Vein" or

No. 3 of Newberry in the Ohio Valley and in the valley of the Yellow Creek, with the Lower Kittanning coal, furnishes an excellent and settled base for our sections. We know what is due below it and above. From 40′ to 60′ above it, the horizon of the Ferriferous limestone should be found, and from 140′ to 200′ below it, the Lower Mercer series is due. To reach the place of the lowest coal, we should be obliged to descend 100′ to 150′ below the Lower Mercer limestone.

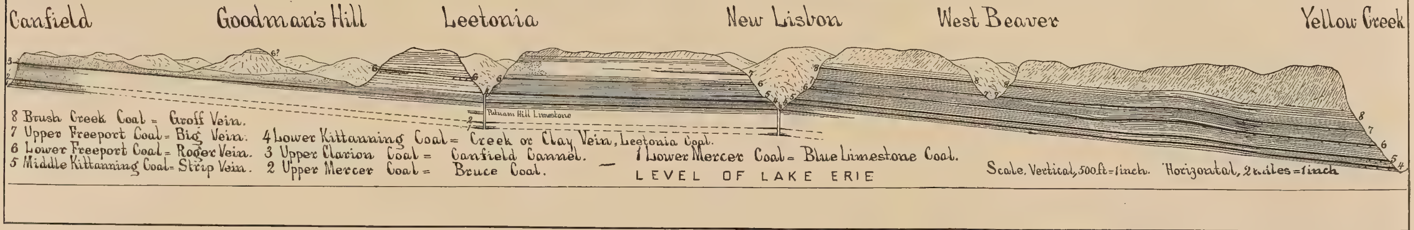
As to what is above the Creek Vein, there is no controversy, aside from the names to be given to one or two elements. The Freeport series extends through the hills in visible and unquestioned continuity.

The section of the Yellow Creek Valley is so fully described by Newberry (Geol. of Ohio, vol. III, p. 93), that little needs to be added to his account. It is as follows: "Coming into the valley of Yellow Creek from that of the Ohio, we find it bounded at its mouth by hills, rising to the height of 500 to 600 feet, which contain five workable seams of coal."

"Of the larger seams, the lowest is called the *Creek Vein,* because it lies near the level of Yellow Creek, from Linton up as far as Irondale. This is a coking, bituminous coal of moderately good quality, but rather soft and containing considerable sulphur. From 18′ to 30′ above this, lies what is called the *Strip Vein,* from the fact that it was formerly worked by stripping off the soil and earth which covered its outcrops. The seam has an average thickness of 2½ feet, and is of great excellence wherever it is opened in the valley. The interval between this coal and the Creek Vein is mainly occupied by black shale, which contains a notable quantity of nodular iron ore; it also contains in places a stratum of limestone 3′ to 4′ in thickness. About 50′ or 60′ above the Strip Vein at this point occurs another seam, which is here thin, but higher up the valley it attains a thickness of from 3′ to 3½′, and is known as the *Roger Vein.* At a variable distance above the Roger Vein occurs what is known as the Big Vein, in dimensions, the most important seam in the valley. About 60′ above the Big Vein, the interval being filled with black and gray shale, sandstone, and a bed of limestone, occurs a coal seam known here as the *Groff Vein,* from 4′ to 5′ in thickness, of very good quality."

FIGURE XIV

SECTION FROM CANFIELD TO HAMMONDSVILLE



"The coal seams enumerated in the above sketch are supposed to be

No. 3	Creek.
No. 4	Strip.
No. 5	Roger.
No. 6	Big.
No. 7	Groff.

of our lower group of coals."

Two sections, taken respectively near the mouth of the creek and at Hammondsville, exhibit these facts, Fig. XIII:

By comparing the sections in Fig. XIII, with the general section of Lawrence county, Penn., Fig. II, or with the actual sections at New Brighton and Smith's Ferry, Figs. III and IV, it will be seen that they are in sufficiently close accord, and interpretation would be superfluous.

At the mouth of Yellow Creek, we are nearly due south of the point at which our sections were begun. The distance is about 33 miles. In the horizontal section, Fig. XIV, the connections and continuity of the seams as now described are roughly represented. The low arches that traverse the series at several points are not accurately indicated in the section, except as the varying dip may suggest their locations. The numbers used to designate the several elements, have nothing to do with any system of numbering or designating the coal seams.

The Steubenville Shaft Coal.

From the mouth of Yellow Creek, a line of sections along the hills that border the Ohio Valley carries us to Steubenville. The sections can be followed on the appended sketch map of Jefferson county. The distance is 17 miles; the direction a trifle east of south. The prevailing dip is to the southward, but the region is traversed by one or more low folds, which produce some irregularity in this respect, a strong, westerly element showing at one point.

For the most part the sections are easy to interpret and free from ambiguity and question. The Lower Kittanning coal with its heavy and valuable bed of clay, makes an easily recognized base for most of them. The clay is the basis of a very extensive and thriving business in the manufacture of fire brick, sewer-pipe and terra-cotta ware, which

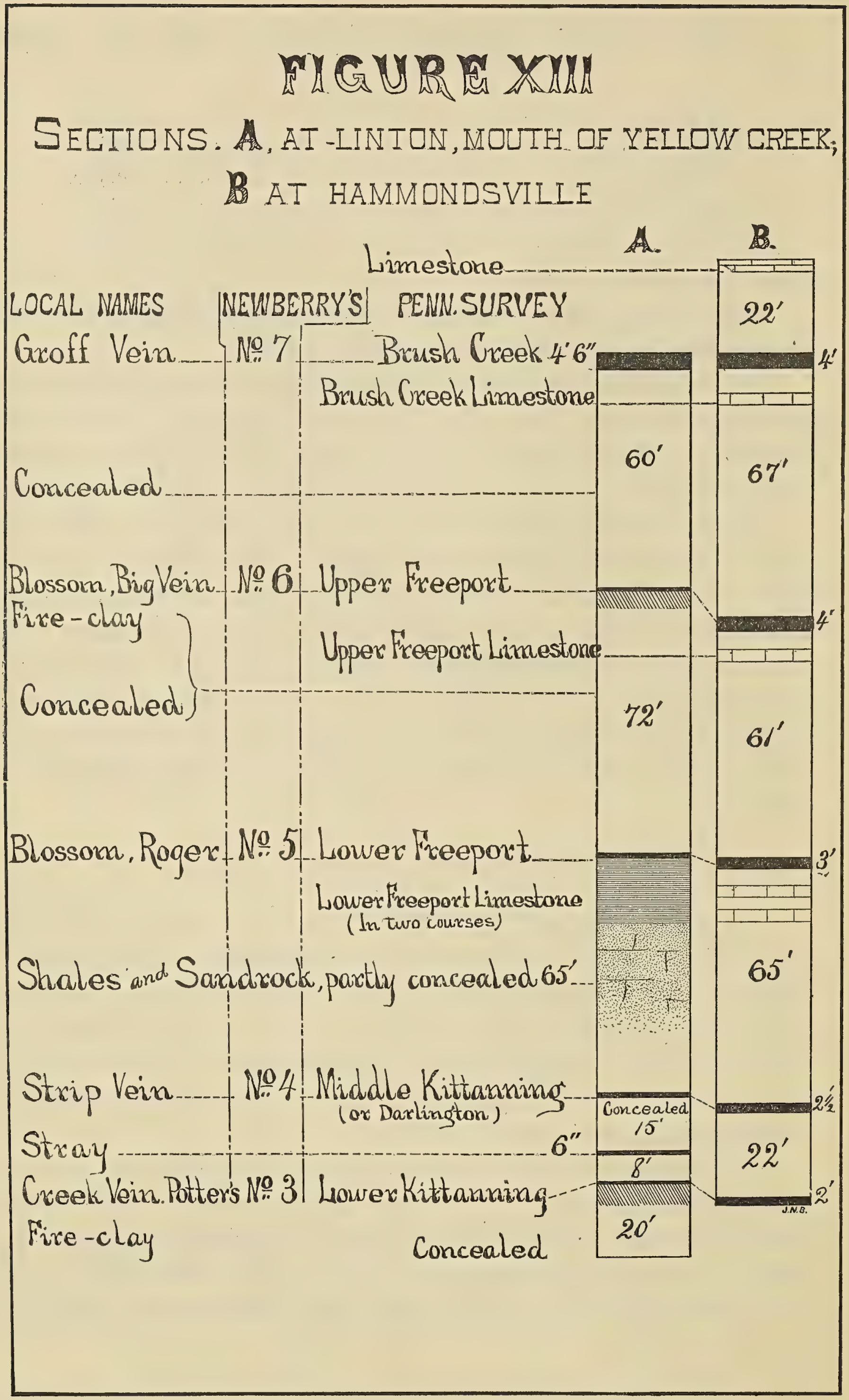


FIGURE XIII
SECTIONS. A, AT LINTON, MOUTH OF YELLOW CREEK; B AT HAMMONDSVILLE
A.
B.
Limestone
LOCAL NAMES
NEWBERRY'S
PENN. SURVEY
22′
Groff Vein
№ 7
Brush Creek 4′ 6″
4′
Brush Creek Limestone
60′
67′
Concealed
Blossom, Big Vein
№ 6
Upper Freeport
Fire-clay
4′
Upper Freeport Limestone
Concealed
72′
61′
Blossom, Roger
№ 5
Lower Freeport
3′
Lower Freeport Limestone
(In two courses)
Shales and Sandrock, partly concealed 65′
65′
Strip Vein
№ 4
Middle Kittanning
(or Darlington)
Concealed
15′
2½′
Stray
6″
22′
8′
Creek Vein. Potter's № 3
Lower Kittanning
2′
Fire-clay
20′
Concealed
J.N.B.

extends along the valley for more than half of the distance to be traversed. The coal is known as the Clay Vein, the Potters' Vein, the Sulphur Vein and the Creek Vein. Above it lies the Middle Kittanning coal, here known as the Strip Vein or the Block Vein. The seam is thin, but its quality is generally excellent, and it is worked in many small mines. The interval between the two Kittanning coals ranges from 18′ to 30′, but the average would not be much more than 20 feet.

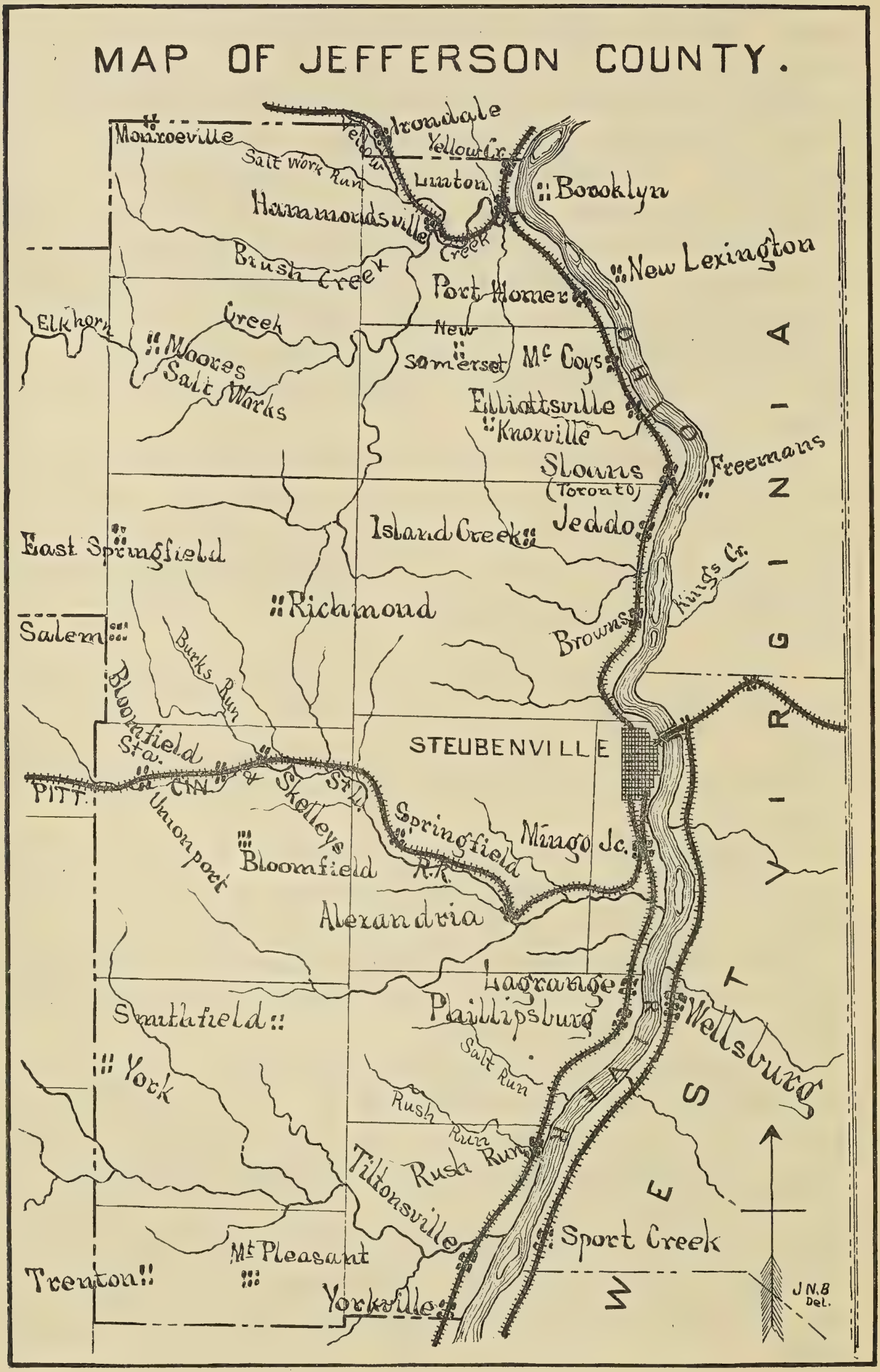
A seam not before reported makes its appearance in almost all of these sections. It lies about 40 feet above the last named seam, and in accordance with the Pennsylvania notation may be designated as the Upper Kittanning coal. It is commonly called the 18-inch vein, and though thin, is opened in many local banks for household supply. Its quality is good.

The main coal of the valley is, however, the Lower Freeport seam, which is here known as the Roger Vein. The interval between it and the Clay Vein ranges from 86 to 140 feet, and averages about 110 feet. This seam is of fair thickness, viz., 3 to 4 feet throughout a good deal of territory, and the quality is also good. It is always underlain with its limestone.

The Upper Freeport coal, the Big Vein of Salineville and the Yellow Creek Valley, has but a very sparing development south of Yellow Creek. A "blossom" frequently marks its place, and its limestone is sometimes met, but the coal itself has not been found south of Yellow Creek Station.

The Brush Creek coal, which is the Strip Vein of Salineville and the Groff Vein of the lower Yellow Creek Valley (Newberry's No. 7, throughout this region) is a much more constant element. It is worked at a number of points, and is everywhere of good quality. Its elevation above the Clay Vein ranges from 192 to 225 feet, giving an average of 207 feet for the sections measured.

Two other elements are reached in many of the sections, viz., the Crinoidal limestone and the Pittsburgh coal. The former lies at an average distance of 320 feet above the Lower Freeport coal (Roger Vein), and of 430 feet above the Lower Kittanning. The Pittsburgh coal at the most northerly point that it reaches in the State, viz., in Saline township, at the southernmost bend of Yellow Creek, is 468 feet above the Upper Freeport coal, which would make it about 530 feet above the Lower Freeport seam. This interval increases to the southward.


MAP OF JEFFERSON COUNTY.
Monroeville
Irondale
Yellow Cr.
Salt Work Run
Linton
Brooklyn
Hammondsville
Creek
Brush Creek
New Lexington
Port Homer
Elkhorn
Creek
Moores Salt Works
New Somerset
McCoys
Elliottsville
Knoxville
Sloans
(Toronto)
Freemans
Jeddo
Island Creek
East Springfield
Kings Cr.
Richmond
Browns
Salem
Burks Run
Bloomfield Sta.
STEUBENVILLE
PITT.
CIN. & ST.L.
Unionport
Skelleys
Springfield
Mingo Jc.
Bloomfield
R.R.
Alexandria
Lagrange
Phillipsburg
Wellsburg
Smithfield
Salt Run
York
Rush Run
Rush Run
Tiltonsville
Sport Creek
Mt. Pleasant
Trenton
Yorkville
OHIO
WEST VIRGINIA
J.N.B. Del.

The relations of these elements to each other can be seen in the following diagram:

Pittsburgh coal.	
Interval	175 to 225 feet.
Crinoidal limestone.	
Interval	120 to 150 "
Brush Creek coal (*Groff Vein*).	
Interval	40 to 50 "
Upper Freeport coal (*Big Vein*).	
Interval	35 to 60 "
Lower Freeport coal (*Roger Vein*).	
Interval	40 to 55 "
Upper Kittanning coal (*Eighteen-inch Seam*).	
Interval	30 to 40 "
Middle Kittanning coal (*Block Vein*).	
Interval	18 to 30 "
Lower Kittanning coal (*Clay Vein* or *Creek Vein*).	
Kittanning clay.	

The first section taken along this line is one mile below the mouth of Yellow Creek. The Middle Kittanning coal here lies at railroad grade. The Roger coal is opened 72 feet above it. The blossoms of the Big Vein and the Groff Vein are seen at the proper elevations. The whole section is as follows:

Brush Creek coal—blossom.	
Interval	50 feet, approximate.
Upper Freeport coal—blossom.	
Interval	60 " approximate.
Lower Freeport coal.	
Interval	72 "
Middle Kittanning coal—level of railroad.	

At Port Homer a larger section is obtained. It is as follows:

Crinoidal limestone.	
Interval	180 feet.
Coal, thin, 6 inches.	
Interval	28 "
Brush Creek coal, Groff Vein—blossom.	
Interval	57 "
Upper Freeport limestone, 2 feet.	
Interval	138 "
Lower Kittanning coal, 2 ft. 6 in. (7 ft. below railroad).	

As seen in the last section, the strata are rising slowly to the southward, the Clay Vein coal having risen almost to railroad grade. It is found level with the track, one-half mile above McCoy's station. The Groff coal is worked here, 210 feet above the Clay Vein.

Brush Creek coal.	
Interval	210 feet.
Lower Kittanning coal.	

Near McCoy's Station, at Einsinger's Hill, the following elements occur:

Crinoidal limestone, 4 fee	
Interval	278 feet.
Lower Freeport coal, once mined here.	
Interval	120 "
Lower Kittanning coal, 3 ft.	

One-half mile below McCoy's, at Porter, Miner and Co.'s works, we find the Clay Vein 8 feet above the railroad. The following section section was obtained here:

Brush Creek coal, outcrop.	
Interval	72 feet.
Coal (LowerFreeport?), once worked.	
Interval	77 "
Upper Kittanning coal, 18-inch vein worked.	
Interval	63 "
Lower Kittanning coal, 2 ft. 6 in.	

From near this point the southerly dip, which has been interrupted for a few miles, is resumed and the worked outcrop of the Lower Freeport coal is seen to fall off rapidly to the southward. The coal seam which is marked with a question may possibly be the Upper Freeport, but with such facts as we have to judge from, it is more like to be the Lower Freeport seam, but the interval is excessive.

At Freeman Brothers Clay Works, ¾-mile below McCoy's Station, the Clay Vein and Roger Vein are both worked. The interval is 106 feet.

Lower Freeport coal.	
Interval	106 feet.
Lower Kittanning coal.	

At the Calumet Clay Works, at Elliottsville, we find an excellent section comprising among other elements the following:

Coal—	
Upper Clay seam.	
Interval	51 feet.
Brush Creek coal, 3 ft. 8 in., once mined.	
Interval	120 "
Lower Freeport coal, 3 ft., mined.	
Interval	86 "
Lower Kittanning coal, 3 ft. } mined.	
Kittanning clay, 8 ft. } mined.	

The shaft sunk at the works to reach the lower bed of clay, which was first found at Walker's Station, gives the following record:

Blue rock	9′	6″
Hard grit	1′	6″
Soapstone	2′	6″
Gritty slate	4′	
Fossiliferous limestone (Ferriferous?)	3′	6″
Sandy slate	9′	3″
Black slate	0	9″
Hard gray grit	0	4″
Black slate	12′	6″
Blue-black slate—micaceous	14′	
Fossiliferous limestone (Putnam Hill?)	1′	
Fossiliferous slate	4′	
Slate, soft, 6″ coal near top (Brookville?)	10′	
Clay, Lower Vein	12′	
Clay and slate	10′	

Drilling carried below the bottom of the shaft lengthens the record thus:

Interval	54′	
Coal	0	10″
To bottom of hole	19′	

The identification of the limestones is not made positive, but no good ground for objection to it is recognized. The Clay Vein coal is a few feet below railroad grade.

At the works of the Great Western Fire-clay Company, half-way between Elliottsville and Toronto, the interval between the Clay Vein and Roger coal, both of which are worked, is 85 feet. The Clay Vein has fallen here to 40 feet below railroad grade.

Lower Freeport coal.	
Interval	85 feet.
Lower Kittanning coal.	

At Toronto (Sloan's Station) the following section was obtained, in part, from the new shaft record:

Brush Creek coal, 4 ft. formerly mined.	
Interval	80 feet.
Lower Freeport coal, 28 to 40 inches mined.	
Interval	86 "
Middle Kittanning horizon, black shale.	
Middle Vein clay, 7 ft.	
Interval	22 "
Lower Kittanning coal, 3 ft. 5 in.	
Kittanning clay, 6 ft. 6 in.	

The last-named coal is about 30 feet below railroad grade.

One mile below Toronto, near Jeddo Station, the Lower Freeport coal is worked, 25 feet above railroad grade. On Thomas Wells's farm, half-way between Jeddo and Brown's Station, the same coal is found 10 ft. above the railroad. At Brown Station, it is found near the level of Island Creek. It rises with the creek to the northward, and was formerly worked in the large way for the use of the salt wells of this valley. It is 77 feet below the well-known coal mined on Wm. S. Finley's farm, which, as all agree, is the equivalent of the Groff or Brush Creek seam.

The Lower Kittanning seam has now gone below drainage, and henceforth the Lower Freeport coal will be taken as the base of the sections by which the continuity is to be maintained.

At G. W. Peacher's mill, half-way between Finley's mines and the river, the Lower Freeport coal is worked. It here lies 336 feet below the Crinoidal limestone.

At the mouth of Island Creek, the following section is found:

1.	Brush Creek (?) coal,	1	foot	6	inches.
2.	Interval	65	feet.		
3.	Yellow limestone	3	"	6	"
4.	Bolivar clay (and shale),	13	"		
5.	Upper Freeport limestone, nodular	2	"	6	"
6.	Interval	26	"		
7.	Lower Freeport coal	1	"	6	"

This section is of special value, inasmuch as it shows a characteristic development of the Upper Freeport horizon. It seems probable that the yellow limestone above the clay represents the Upper Freeport coal. These buff limestones frequently come in upon the horizons of the coal seams, apparently replacing them. The clay is the non-plastic, greenish fire-clay, so characteristic of the horizon. It has been worked here in years past, the brick made from it having a good reputation. The clay takes its name from Bolivar, Pa., where it has long been mined and worked. The limestone below is in all respects characteristic Upper Freeport limestone.

The Island Siding Brick Works, a short distance below Brown's Station, are working a clay and shale that comes from above the upper limestone, but they have also used the hard clay between the limestones. The chief objection to this clay is that nuggets of limestone occur in it which can be kept out of the worked product only by great care.

Crossing the river from Toronto, we find on the West Virginia side the same general section that we have been following.

At Freeman and Co.'s Works, the following section was obtained:

1.	Brush Creek coal, Groff vein	3′	6″
2.	Interval	51′	
3.	Limestone, in place of Upper Freeport coal (?)	2′	
4.	Shales with ore balls	3′	
5.	Non-plastic clay (Bolivar ?)	6′	
6.	Shale and sandrock, Upper Freeport	34′	
7.	Lower Freeport coal, Roger Vein	2′	6″
8.	Fire-clay	3′	
9.	Sandrock and sandy shale, Lower Freeport	69′	
10.	Coal, 18″ vein or Middle Kittanning	2′	
11.	Fire-clay	2′	
12.	Sandrock and shale	49′	
13.	Lower Kittanning coal, Clay Vein	2′	
14.	Kittanning clay, mined	6′	
15.	Concealed to river	47′	

At W. B. Freeman's Clay Works, the Middle Kittanning or Strip Vein coal comes in to the section, as follows:

1.	Lower Freeport sandstone, exposed		25′	
2.	Middle Kittanning coal (Strip Vein)	Coal, 1′ 0 Slate, 0 1″ Coal, 1′ 6″	2′	7″
3.	Fire-clay and concealed		27′	
4.	Lower Kittanning coal (Clay Vein)		2′	
5.	Kittanning clay		6′	

From the point last named to the mouth of King's Creek, 1½ miles below, the two lower coals hold the same relative position as that just given.

At Porter & Co.'s Brick Works, the Lower Freeport coal is also found. The section is as follows:

1.	Lower Freeport coal	3′	6″
2.	Interval	60′	
3.	Middle Kittanning coal, Strip Vein	3′	
4.	Interval	30′	
5.	Lower Kittanning coal	3′	
6.	Kittanning clay	6′	

This point is about ½ mile above the mouth of King's Creek. The Roger coal is worked at many points in this valley, and is quite widely known as the King's Creek coal. It can be traced on every farm.

At the Tarr Brothers' farm, 2 miles above the mouth of the creek, the following satisfactory section was found:

1.	Crinoidal limestone	1′	
2. 3.	Shales, sandy shales, and— Sandrock, partly concealed	218′	
4.	Brush Creek limestone	1′	
5.	Sandy shale and sandrock	52′	
6.	Bituminous shale	0	3″
7.	Shale and fire-clay	2′	
8.	Limestone, place of Upper Freeport coal	1′	4″
9.	Non-plastic fire-clay (Bolivar), in pockets	5′	
10.	Shale with calcareous nodules and clay	4′	
11.	Shale	20′	
12.	Lower Freeport coal { Bone coal, 0 6″; Coal, 3′ 0; Slate, 0 2″; Coal, 1′ 0 }	4′	8″
13.	Fire-clay and concealed to creek	23′	

The Lower Freeport limestone is also shown at intervals along the creek. The coal ranges from 3 ft. 6 in. to 5 ft. Its structure, as given above, is modified somewhat in different mines. A mine, ¼ mile below the Tarr Brothers' mine, shows the following structure:

Bone coal	0	6″
Coal	2′	0
Slate	0	2″
Coal	1′	2″
	3′	10″

The seam can be followed up the stream by numerous openings as far as Taylor's Mills. It is here reduced to 2 ft. in thickness, and lies between the Upper and Lower Freeport sandstones.

One more section in which the Clay Vein coal occurs can be found on the West Virginia side of the river. At Thompson and Miller's brick-yard, just below the mouth of King's Creek, the Lower Kittanning horizon appears for the last time above the river level. The section is as follows:

1.	Shales, exposed	10′
2.	Lower Freeport coal, King's Creek seam	2′
3.	Sandy shales and sandrock (L. F. sandstone, etc.)	95′
4.	Middle Kittanning coal, Strip Vein	3′
5.	Fire-clay	4′
6.	Shale and sandrock	17′
7.	Lower Kittanning coal, Clay Vein	2′
8.	Kittanning clay, mined	8′
9.	Concealed to low water	4′

It will be profitable to recapitulate the facts pertaining to the Lower Freeport or Roger coal, which is here known as the King's Creek coal:

1. It ranges from 2 ft. to 5 ft. in thickness.
2. It is a little more than 300 ft. below the Crinoidal limestone (308 ft. on the Tarr farm).
3. It ranges between 90 ft. and 120 ft. above the Lower Kittanning coal.
4. The Upper Freeport clay and limestone occur about 35 ft. above it.

Returning to the Ohio side of the river, we find no exposures of the lower coals between Island Creek and Will's Creek, but the Crinoidal limestone sweeps from hill to hill, and furnishes a constant upper limit for our sections. On the north bank of Will's Creek, a half mile above its mouth, we find the limestone in the middle of a long section, which is continued downwards, by a well record reported by Newberry in volume III, pp. 753–4.

The main elements are as follows:

Crinoidal limestone, underlain by 2 ft. 6 in. coal.	
Interval	265 feet.
Coal, near level of creek, 3 ft. reported, Brush Creek. (?)	
Interval	66 "
Lower Freeport coal, 4 ft., underlain by clay and limestone.	

The Lower Freeport coal is here, as everywhere else throughout this region, a little more than 300 ft. below the Crinoidal limestone. The distance in this measurement is 331 ft. On Island Creek it was found to be 336 ft. On King's Creek, on the other side of the river, it is 308 ft. The coal makes one more appearance in the main valley before it dips below the surface. Just above the mouth of the creek, it is found level with the river at low water.

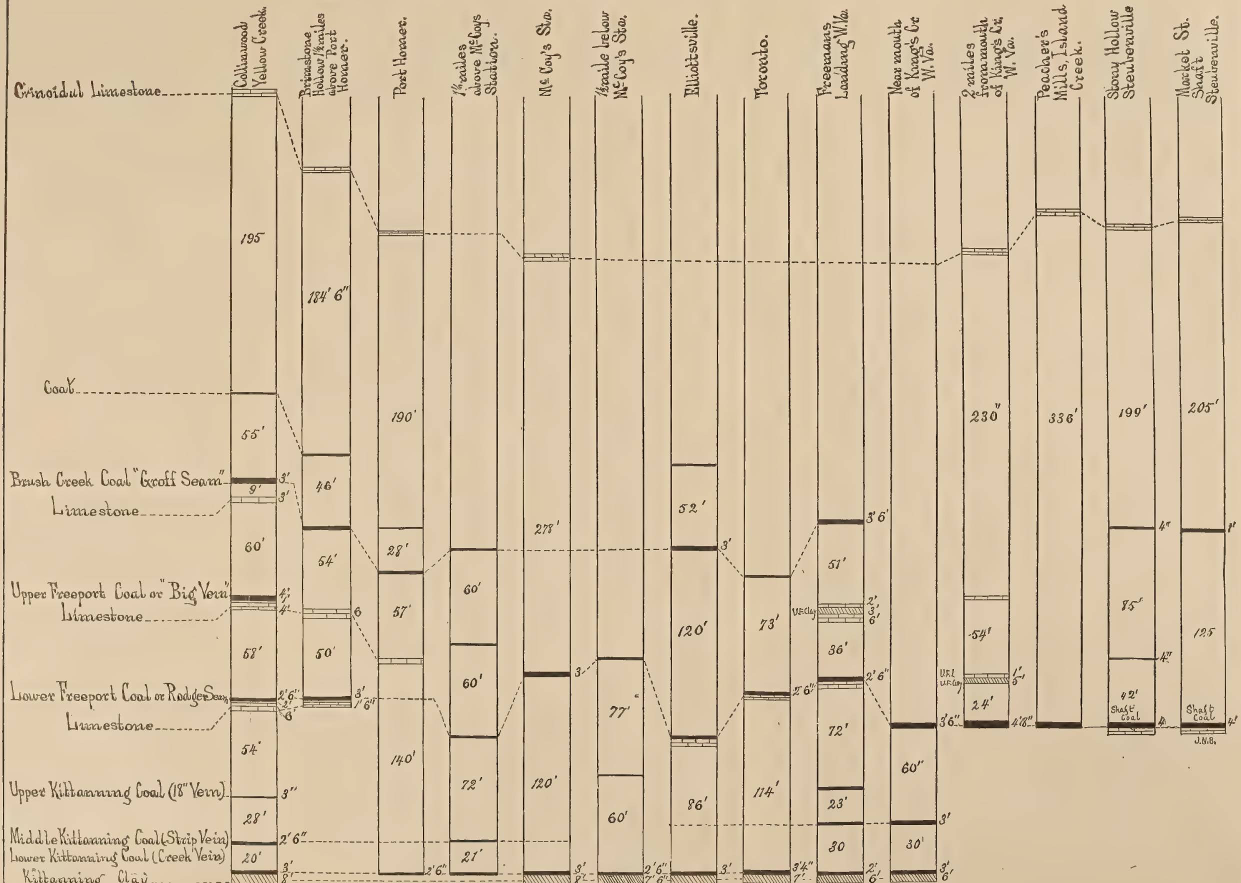
From this point on, Newberry's account of it is clear and succinct. In vol. III, page 756, he says, "the limestone coal of the Wills Creek section" (the Lower Freeport of our last section) "is plainly the shaft coal of Steubenville. It is exposed in the bed of the Ohio just above the mouth of the Wills Creek; is reached at the depth of 75 feet in the shaft of Cable and Co.; at 80 feet in the Bustard shaft; at 172 feet in the boring at Stony Hollow; at 188 feet in the rolling mill shaft; at 204 feet in Averick's shaft; at 221 feet in Boreland's shaft, and 234 feet at the Mingo shaft. At Mingo, Borelands and the Bustard shaft, a band of nodular limestone was found just below the fire-clay, as in the Wills Creek boring." But furthermore we find in the relations of the Crinoidal limestone, confirmatory proof of the conclusion just reached that the Steubenville shaft coal is the Lower Freeport or Roger seam. This persistent stratum is found directly above each of the following named shafts at Steubenville, viz., Alicanna shaft, Stony Hollow shaft, and Market Street shaft. In the first the interval between the shaft coal and the Crinoidal limestone is 313 feet, in the second, it is 326, and in the third it is 330 feet. Gathering up all the measures that we have thus far found of the interval in question, we obtain the following series. A second column shows the interval between the Clay Vein and the limestone:

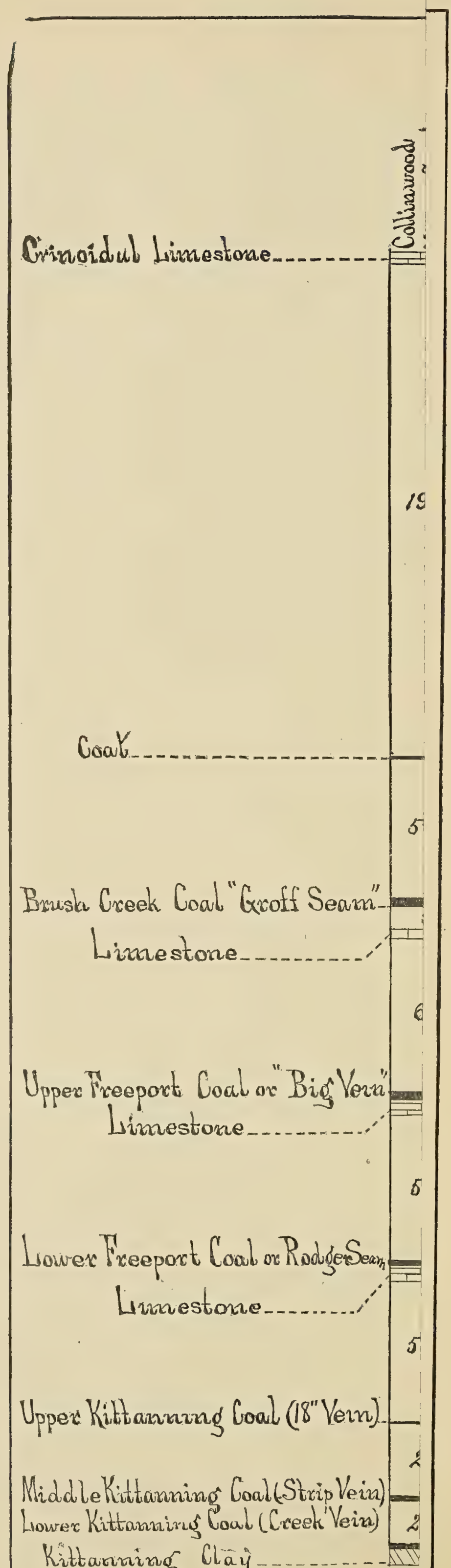
At south bend of Yellow Creek	*342′	427′
At Port Homer	*328′	417′
At McCoy's Station	278′	401′
At Peacher's Mills, Island Creek	336′	*446′
At King's Creek	308′	*408′
At Wills Creek	331′	
At Alicanna shaft, Steubenville	313′	
At Stony Hollow shaft	326′	
At Market Street shaft	330′	

* The figures marked with an asterisk were not obtained from the measurement of single sections but by combining two sections from the same vicinity.

FIGURE XIVA.

LINE OF SECTIONS FROM YELLOW CREEK TO STEUBENVILLE.




Collinwood
Crinoidal Limestone
Coal
Brush Creek Coal "Groff Seam"
Limestone
Upper Freeport Coal or "Big Vein"
Limestone
Lower Freeport Coal or Rodger Seam
Limestone
Upper Kittanning Coal (18" Vein)
Middle Kittanning Coal (Strip Vein)
Lower Kittanning Coal (Creek Vein)
Kittanning Clay

These figures show the steadiness of the sections as a whole. There is more play in some of the intervals than is usual, but in the large way the surprising regularity that characterizes the rest of the Ohio coal field, appears here also.

The facts are represented to the eye in the accompanying plate, Fig. XIV A.

The place thus given to the Steubenville shaft seam in the Ohio series of coals differs from that previously assigned to it. Newberry strongly inclines to the view that the Steubenville seam is the Upper Freeport, though he does not consider the question demonstrated. He seems to count the Groff or Brush Creek seam as the only competitor of the Upper Freeport for this place, but why the claims of the Roger or Lower Freeport seam should have been overlooked until now, it is not easy to see. The Roger seam corresponds better in every way in the matter of intervals, as all can see, but undue stress need not be laid on this point, because of the fact that the interval between the Upper and Lower Freeport horizons in this region does not exceed the play of the sections reported.

The Roger coal is a persistent seam through the district, across which our sections have carried us. Mines are opened in it for almost every mile of the interval between Yellow Creek and Island Creek, where it falls to the drainage level. On the other hand, the Upper Freeport coal does not appear as a mineable seam at a single point in this interval.

The interval between the Roger and the Groff coals is shorter at the end of this line of sections than it was at the beginning, it is true, but the change is progressively accomplished. At Hammondsville, the measurement is 125 feet. At McCoy's it is 85 feet, at Toronto 80 feet, at Island Creek 77 feet, and at Wills Creek 65 feet. The principal change has been accomplished in a part of the field where there is no dispute in regard to the elements.

It cannot be objected that the Roger coal is not a seam of sufficient thickness to represent the Steubenville coal, for it rises to 5 feet on King's Creek, while the Steubenville shaft coal falls to 28 inches at Mingo. In any case the Roger coal is the thickest as well as the steadiest seam that is to be found in all the region to the north of Steubenville.

No argument can be raised against the identification on the score

of quality. The average of the Roger coal is not as good as the best of the Shaft coal, but there is no other seam that would fare better in such a comparison. It is also true that as poor a quality is found in some of the shaft seam mines as in any of the mines of the Roger coal, outside the limits of the shaft seam field.

It may be objected that the coals reported below the Steubenville coal in shafts and well records cannot be as satisfactorily accounted for on this identification as on that previously given. The objection has but little weight. If all the facts of the series that lie open to-day can be harmoniously adjusted, we need not allow the obscure and often distorted sections of well records to perplex us overmuch. But there are no serious difficulties to be reconciled. The first coal seam found below the shaft coal comes in very well, as far as interval is concerned, for the Upper Kittanning or 18-inch seam. The intervals as recorded are 28 feet in the Alicanna shaft, 44 feet in the Rolling Mill shaft, 45 feet in the McElroy well, 54 feet in the Market Street test well, and 52 feet in the Mingo well. The reported thickness does not agree as well. This is given as 4 feet, cannel coal, in the McElroy well, and as 2½ feet at several other points. It is reported "thin" in the Mingo well. The Upper Kittanning seam nowhere shows 2½ feet in its outcrops.

The second seam below the Shaft coal is reported at 80, 92 and 98 feet, respectively, in three wells. If these figures stand for the same seam, it could be either the Middle or Lower Kittanning, without doing violence to the sections obtained elsewhere.

As to the coal seam, 3 ft. 9 in. thick, reported 139 feet below the Shaft coal in the Mingo boring, it is scarcely worth while to essay an identification. There are seams enough to compete for the place. A fairly probable determination would make the 80 to 100 feet coal the Middle Kittanning or Strip Vein, and 139 feet seam, the Lower Kittanning or Clay Vein. In any case, there are more coal seams shown in vertical section at Steubenville than at any other point in Ohio, as far as is now known.

In view of the facts that have now been presented, the place of the Steubenville Shaft seam in the series is counted definitely settled. It is the Lower Freeport coal of the general section, and the Roger seam of the Ohio and Yellow Creek valley.

The credit for working out the essential facts in this demonstration belongs to F. W. Sperr, M.E., an assistant on the survey.

THE COAL SEAMS OF THE BIG SANDY CREEK VALLEY.

Returning from the Ohio Valley to the northern margin of the coal field, we shall find the most advantageous line of sections along and in the vicinity of the Cleveland and Pittsburgh Railroad.

The series last described can be followed up Yellow Creek to Salineville with unmistakable distinctness, as so well shown by Newberry (vol. III, p. 100). It is lost in the Yellow Creek Summit of the railroad, but its upper members promptly reappear on the northern side of the divide as soon as their level is reached. Newberry's description and reference of the coal seams found to the northward can be quoted and adopted without qualification. It is as follows:

"Going north from Salineville toward New Lisbon, the road passes over a divide of which the summit is 350 ft. above Salineville Station. . . . Descending the divide toward the north, and coming down into the valley of the West Fork of Little Beaver, near Gaver Post-office, we find the shales of the Barren Measures succeeded below by a heavy sandrock and two coals, the upper 2 ft. 8 in. to 3 ft. thick, of excellent quality, and resembling the Salineville Strip Vein (No. 7). The second seam, some 60 ft. lower, is not well shown where first seen, but further down the stream, toward and at West Point, both these coals outcrop and are worked at numerous localities. Beneath the lower one, which is five feet in thickness, and separated from it only by the fire-clay, is a limestone. This coal can be traced north and east from this point to the limits of the county, and is distinctly recognized everywhere as the Big Vein. It is our Coal No. 6, the Upper Freeport coal of Pennsylvania."

The Upper Freeport coal and limestone can be followed westward from Gaver's Post-office to Millport on the Cleveland and Pittsburgh Railroad. The interval between the coal and limestone slowly increases to the northwest until a maximum of 25 ft. is reached. The coal disappears temporarily near the railroad, but the limestone is found here about 6 ft. above the level of the track. At Kensington, the coal comes in again, and the limestone is found 25 ft. below it. It was formerly quarried here from the bed of the canal. From this point northwards the coal is frequently opened. At Rochester Station it has been mined for a number of years by William Somerville. The section here is as follows:

1.	Heavy sandrock		
2.	Upper Freeport coal	Coal, 1′ 6″ to 4′; Shale, 1″ to 2″; Coal, 2″ to 1′ 4″	5′ 6″
3.	Fire-clay and shale		25′
4.	* Upper Freeport limestone (?)		1′–3′
5.	Shale		5′
6.	Coal outcrop, cannel.		

Whether No. 6 in the section represents the Lower Freeport coal is uncertain, as this element has but a feeble development throughout this region, though its limestone is frequently found, but it may be so counted provisionally. On the south side of the divide, the two Kittanning coals are found at 125 ft. and 150 ft. approximately below the Upper Freeport coal. A boring made by Mr. Somerville at Rochester shows two seams that hold the exact places of the Kittanning coals, the section being continued downwards from the cannel coal last named:

7.	Sandstone, shale and fire-clay	86′
8.	Middle Kittanning or Darlington coal	2′ 6″
9.	Shale, etc	38′
10.	Lower Kittanning coal, hard and clear	2′ 6″

The same facts can be represented in another form:

Upper Freeport coal (118 ft. interval).
Middle Kittanning (?) coal (40 ft. interval).
Lower Kittanning (?) coal.

The last-named seam is thus seen to be 158 ft. below the Upper Freeport coal. In the Hammondsville section it will be remembered that the interval between the Lower Kittanning and the Upper Freeport coals is close to 150 ft.

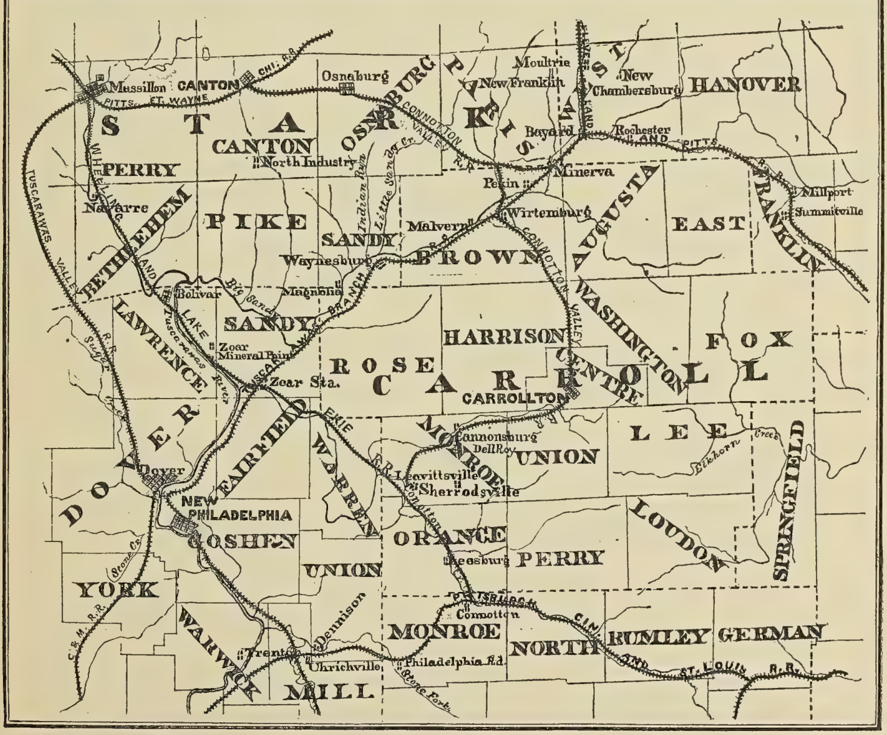
The elevation of the Somerville coal above Lake Erie is 585 ft. The Middle coal is accordingly 462 ft. at this point, and the Lower coal 422 ft. above the same base. The Upper coal rises a little higher before it reaches the Sandy Summit where its elevation is not far below 600 ft. As the coal now lies high in the hills, it is of course cut out by the Sandy Valley, which the railroad crosses, but to the northward, both coal and limestone are found as soon as summits are reached that are high enough to hold them. Both elements also hold their places continuously to the westward from Rochester, through Augusta and Brown townships of Carroll county.

* Found in adjoining farms.

We may safely follow the clue furnished by the two coals disclosed in the boring made by Mr. Somerville at Rochester, and which have been identified provisionally as the Middle and Lower Kittanning coals, by reason of their positions in the series.

In coming down from the Sandy Summit to Bayard, we descend over 100 ft. (Bayard, 503 ft, above L. E.), but not low enough to reach the coals reported in the Rochester boring, which are 462 ft. and 422 ft. above L. E. To find lower ground, we must descend the Big Sandy Valley. The railroad grade drops 23 ft. in reaching Minerva, 2 miles below Bayard (480 ft. above L. E.), and here just outside the limits of the corporation, on the south side of the creek, the upper of the two coals comes to day, with an altitude of 469 ft. above L. E. On the same farm (James Carson's), the Lower coal is also found, level with the water, at approximately 440 ft. above L. E. The upper seam is being mined here at the present time. It has a thickness of 2 feet to $2\frac{1}{2}$ feet.

SKETCH MAP of STARK, TUSCARAWAS and CARROLL COUNTIES IN PART.



From Minerva to Magnolia and Mineral Point, there is not only no difficulty in following, but there is no possibility of losing, these two companion seams as they stretch along the sides of the valley. The upper one has been worked or at least opened for every mile, not to say on every farm, in the interval. The lower one is frequently opened and worked, and it is everywhere true to its place, from 25 to 40 feet below the upper seam. It is still a "Clay Vein." It covers throughout the valley a heavy deposit of clay which assumes a phase of unusual purity and excellence about Magnolia and Mineral Point, where it has long been worked in the large way.

At 60 feet below the lower seam, the well-known Gray or Putnam Hill limestone is found in the lower portion of the valley. It has been traced by borings and by shafts eastward as far as Waynesburgh, where it lies from 20 to 30 feet below the bed of the stream. This limestone covers a coal seam which has the best right to be counted Coal No. 4 of all the separate seams which bear this designation.

The two seams already described as lying above it, are Newberry's coals No. 5 and No. 6 of the Tuscarawas Valley series, but they are just as certainly the Middle and Lower Kittanning coals of the Pennsylvania scale, or No. 3 and No. 4 of the Yellow Creek section, which we have just left behind us.

The strata lie very nearly level throughout the Sandy valley, or in other words, the valley extends in the direction of the line of strike, but there is a light dip to the south and east throughout this region generally. The elevations above Lake Erie of the Middle Kittanning (No. 6 of Newberry's Tuscarawas series) through the valley are as follows:

	Feet.
Somerville's mine, Rochester Station, boring	462
Minerva and Pekin	469
Oneida	450
Malvern	440
Waynesburgh	448
Two miles below Magnolia	482
Four miles below Magnolia, east of tunnel	476

At the last station the following section is found:

Above L. E.		Ft.	In.
	Shale.		
476′	*Coal*—"Upper Vein," Middle Kittanning, mined (No. 6 of Newberry)	3	
	Fire-clay	3	

Above L. E.		Ft.	In.
	Slate rock	15	
	Coal—Eighteen-inch vein	1	6
	Shale	22	
436′	*Coal*—"Lower Vein," Lower Kittanning (No. 5 of Newberry)	3	6
	Fire-clay, 3 ft. 8 in	3	
	Shale and sand-rock	62	
	Gray limestone—Putnam Hill, fossiliferous	1	8
369′	*Coal*—"Limestone Vein," Brookville seam (?) (No. 4 of Newberry)	5	
	Level of Big Sandy.		

We have followed the line of the Tuscarawas branch of the Cleveland and Pittsburgh Railroad up to this point, using its levels to determine the elevations of the several geological elements. The road here turns away from the valley of the Big Sandy, and bears to the southward. Following the valley north-westward to Bolivar, we find a number of clear and valuable sections.

One-half mile west of Bolivar, on the David Belknap farm, the following instructive section is found :

Above L. E.			Ft.	In.
	1.	Drift	12	
481′	2.	*Drab limestone*, fossiliferous, Ferriferous of Penna	3	
	3.	Shale	30	
448′	4.	*Gray or Putnam Hill limestone*	2	6
	5.	*Coal*—"Limestone Vein" (No. 4 of Newberry)	2	
	6.	Shale	30	
	7.	*Coal*—Tionesta of Penna. (?), mined here (No. 3*b*)	3	
	8.	Shale	10	
	9.	*Blue or Gray limestone*—"Middle Vein," Upper Mercer (place of Coal No. 3*a*)	2	6
	10.	Fire-clay	3	
	11.	Shale	20	
371′	12.	*Blue limestone*—"Lower Vein," Lower Mercer	6	
	13.	*Coal*, thin } Lower Mercer, No. 3 of Newberry		
	14.	Shale, 6 ft. } Lower Mercer, No. 3 of Newberry	7	9
	15.	*Coal*, 1 ft. 6 in } Lower Mercer, No. 3 of Newberry		
	16.	Fire-clay	6	
333′.66	17.	Concealed to canal	24	

The elements of special interest in this section are Nos. 2 and 7. The former shows the *reappearance of the Ferriferous limestone* at its

proper horizon, half-way between the Putnam Hill limestone and the Lower Kittanning coal. The phase here presented is a common one of the limestone throughout the interval of its unsteady development. It is drab-colored, bedded and not nodular, distinctly, but not abundantly fossiliferous. A calcareous sandstone, effervescing freely with acids, but not slaking after roasting, is another common phase of this horizon.

In No. 7 of the section, we find the best exhibition of the *Tionesta coal* of Rogers in all of this region. It is worked quite extensively here for the supply of the country around. In the following section we find a somewhat greater thickness of the seam, but its value is scarcely increased thereby. The seam has a considerable development in the western side of Stark county. The other elements need no comment, as they occur in typical form and at the usual intervals. The distance from the Lower Mercer limestone to the Ferriferous limestone is here seen to be 110 feet, or a little less than the distance in Mahoning county where we left its last exposure (120 feet). The dip from Bolivar to the tunnel section is about 80 feet, the course that we have followed leading up the line of rise.

Two miles northwest of Bolivar on the Joseph Hair farm and near the Fire-clay Works of B. M. Allison & Co., a section taking in nearly the same range as the last is shown. It is as follows:

		Ft.	In.
1.	*Gray or Putnam Hill limestone*	2	
2.	Concealed	25	
3.	{ *Coal*, 1 ft. 8 in. / Slate, 9 in. / *Coal*, 2 ft. 4 in. } Tionesta (No. 3 *b*)	4	9
4.	Concealed	15	
5.	*Dark-blue limestone*, Upper Mercer	3	
6.	Coal, thin, 4 to 6 in.	0	6
7.	Concealed	30	
8.	*Blue limestone*, Lower Mercer	4	
9.	Dark shale	2	
10.	Coal, thin	—	
11.	Dark shale	2	
12.	Fire-clay	6	
13.	Concealed	20	
14.	Blue limestone (occurs occasionally at this horizon)	1	6
15.	Concealed to canal	15	

The Sharon coal is found in basins near the point which we have now reached at a depth ranging from 125 to 180 feet below the Lower Mercer limestone.

Particular attention has been given in this review to the geology of the Big Sandy Valley, because it is here that the dislocation of the series has occurred which has brought so much confusion into the published accounts of the Lower Coal Measures of Ohio.

The points now brought out are these: 1st. The coal seams numbered 5 and 6 by Newberry in the Tuscarawas Valley section can be followed, as all allow and as none can deny, through the Big Sandy Valley from Magnolia to Minerva at levels, for the upper seam, ranging from 480 to 440 feet above Lake Erie, the lower seam holding steady at 25 to 40 feet below the upper. 2d. The Lower and Upper Freeport coals, also numbered 5 and 6 by Newberry, in Columbiana county, were followed from their unmistakable and undisputed developments in the Yellow Creek and the Little Beaver Valleys, along the line of the Cleveland and Pittsburgh Railroad, as far as Rochester Station and the Sandy divide. The Upper Freeport coal is the seam that is mined at Rochester, as all agree, and its altitude above L. E. is 570 feet. The Lower Freeport seam is frequently met, 30 to 40 feet below it. 3d. A boring made at Rochester shows the coal seams, Nos. 5 and 6 of the Tuscarawas series, 120 feet below the Freeport coals, numbered 5 and 6, to the southward.

These facts show with sufficient clearness and certainty the duplication of several of the numbers, and notably the numbers 5 and 6, by which the more important seams of the Lower Coal Measures are designated in Newberry's classification, and it thus becomes apparent that the coal seams of the Tuscarawas Valley cannot be correlated with those of the Ohio Valley by their numbers. But these facts do not stand alone. There are other lines, entirely distinct from the points already made, which serve to confirm in the strongest way the conclusions that have now been reached.

Note may be made in passing that, in character, the Freeport coals are quite different from the Kittanning coals below them. The Kittanning coals, though thin, are quite regular and steady. The Upper Freeport coal is extremely irregular and liable to "wants," but its maximum thickness is double that of the coal below. The Upper Freeport coal, as compared with the Middle Kittanning or lower No. 6 throughout this region, is inferior in quality. It is divided by irregular slate and sulphur "binders" as well as by its regular shale parting, but the lower seam shows only the regular partings. The Freeport coal is

also higher in sulphur as a rule, and generally higher also in ash. The Middle Kittanning coal is always a harder and stronger coal than the Upper Freeport. It is largely used as a domestic coal, whereas, the Upper Freeport is almost exclusively a steam coal.

It will be remembered that in the dividing ridge near Rochester, between the waters of the Middle Fork of Little Beaver and the Big Sandy Fork of the Tuscarawas, the elevation of the Upper Freeport coal is between 570 and 600 feet above L. E. The coal terminates at this point for a number of miles along the railroad from lack of ground high enough to hold it, but as the dip is very light through all this region, as shown in the elevations already quoted of the Middle Kittanning coal, we ought to count upon finding the Freeport horizon again on the north side of the Sandy Valley. Newberry reports it at Moultrie, 6 miles north of Rochester, and also at New Chambersburg and New Franklin on either side. At Moultrie, it is 75 feet above the railroad, or about 600 feet above L. E. (vol. III, p. 104). At New Chambersburg, it is 629 feet above Lake Erie, according to Whittlesey. Its limestone accompanies it here.

This shows the continuity of the horizon, but we need not go so far to reach it. It bounds the Sandy Valley from Bayard to Magnolia on both sides. It is especially conspicuous throughout Paris, Brown and Ross townships. The horizon can be followed, in fact, from this point to the Ohio river in unmistakable distinctness. Throughout Tuscarawas county, there is not an element in the scale better known than the Upper Freeport coal, though under another name.

A few sections taken in Paris and Brown townships will be given to bring out these facts in proper light. In Paris township we can avail ourselves of the levels of the Connotton Valley Railroad to some extent.

The Kittanning coals, Lower and Middle, are both shown at Osnaburg (Nos. 5 and 6 of the Tuscarawas series). The Middle Kittanning coal has been long and extensively worked here. Its elevation above L. E. is 618 feet, and the Lower Kittanning coal is but 15 to 18 feet below it. The Putnam Hill limestone comes in at its proper horizon one mile to the northward, and the Ferriferous limestone is represented 30 feet above it, by a calcareous sandstone. Following the railroad to the southward, the Osnaburg coal is easily traced by frequent mines to Robertsville, Paris township, where also the Lower Kittanning coalis

found, with the same interval as at Osnaburg. The Upper coal has fallen here to 540 feet above Lake Erie. Both coals have been mined in the immediate neighborhood.

The Middle Kittanning coal being 540 feet above L. E., the Upper Freeport, according to the measures last found, should come in at 660 feet above L. E., or thereabouts. On the Shull Hill, one mile north of Robertsville, this seam is found 24 inches thick, but capped with 5 feet of *blackband ore*, at an elevation of 147 feet above the Middle Kittanning coal. This places it at 687 feet above L. E., higher by 20 feet than we had expected to find it. There are two other farms in the same neighborhood high enough to hold it, viz., the Wolf and the McNutt farms, and on both of these the coal, capped with the ore, occurs at the same level. On the Grafton Furnace Company's property, just over the line in Osnaburg township, the distance from the Middle Kittanning to the Blackband coal is 118 feet. On all of these tracts, the ore has been extensively worked. A conclusion which we cannot receive without surprise, is thus forced upon us, viz., that the great blackband horizon of Stark, Carroll, Tuscarawas and Guernsey counties is the Upper Freeport horizon. This conclusion will be shown to be established on the firmest grounds before the subject is dismissed.

Passing down the railroad, we find one mile below Robertsville, on the farm of Joshua Unkefer, a section from the Middle Kittanning coal to the Upper Freeport that is distinct and clear, and that corroborates the measurements already taken.

The Middle Kittanning coal has been opened by the side of and at the level of the railroad, and 147 feet above it we find a characteristic showing of the Upper Freeport horizon, containing coal, clay and limestone. It is as follows:

Upper Freeport coal, rotten and worthless	1	foot.
Fire-clay	4	feet.
Upper Freeport limestone	4	"
Interval concealed	45	"
Sandstone, quarried (Lower Freeport)	12	"
Interval concealed	78	"
Middle Kittanning coal	3	"
Lower Kittanning coal reported below.		

The limestone has been quite extensively quarried and burned on this farm, and also on the adjoining (Eckerman) farm. The interval

from the Kittanning coal to the Upper Freeport limestone is precisely the same as was found between coal and blackband in the section already given.

On the Robertsville road to Minerva, the *Lower* Freeport limestone occurs in good development at several points. One is just above the Robertsville Station, and a second is on the Slagle Hill, near Minerva. The limestone is from 80 to 100 feet above the Middle Kittanning coal.

The southward dip carries the Osnaburg coal down to 450 feet above L. E. at Oneida where the railroad reaches the Sandy Valley. The seam, as has already been stated, is opened on nearly every farm through the valley. At Malvern it is quite extensively worked by T. M. Creighton, in the southwest quarter of section 18, Brown township. The Lower Freeport coal, 2 feet thick, has been opened at just 100 feet above the Middle Kittanning coal on this farm, and near by, on the J. Weis tract, southwest quarter of section 7, an old mine of the Upper Freeport coal is found. The limestone appears in the adjacent ridges in strong force. On the Foltz Hill, it is not less than 8 feet thick, and is thoroughly characteristic in all respects. The Weis coal was but 24 or 25 inches thick. It carried no blackband with it, but it was covered by a considerable body of black shale.

At David Stull's farm, in Sandy township, Stark county, near the western line of Brown, a measurement was again obtained between the Middle Kittanning coal and the Upper Freeport coal. The interval is here 132 feet. The upper coal was found 3 to 4 feet in thickness, and the black shale over it carried iron enough to lead to its being mined on the large scale, many thousand tons being calcined, but it proved too lean an ore to be used with profit.

The Magnolia section already shown on page 92, when extended so as embrace all of the elements that fairly belong to it, proves to be the most comprehensive and the clearest section of the Sandy Valley. It was extended only to the Middle Kittanning coal (No. 6 of the Tuscarawas Valley), but by following this well-known seam ½ mile to the southeast from Magnolia Station, it becomes possible to add 150 feet of overlying strata to the section.

On the V. Rhinehart farm (n.w. ¼ sect. 24, Rose tp.) the coal seam which made the top of our previous section is mined, and on the summit of the hill, which rises above the coal bank, the Upper Freeport horizon is reached. It holds, or rather held, 2 feet of coal, over-

lain with a heavy bed of blackband ore. The area is small, and coal and ore were worked out of it a number of years ago. On the Gibler farm adjoining, and also on the Samuel Creighton farm, the blackband has been opened and worked quite largely. On the Rhinehart land the section is as follows:

Above L. E.			Feet.
	1.	Mahoning sandstone, pebbly	8
	2.	Shale	6
	3.	Blackband ore, 0 to 10 ft. worked out	5
612′	4.	Coal, reported 2 to 3 ft	2
	5.	Fire-clay	3
	6.	Sandstone and shale, and concealed	37
	7.	Lower Freeport sandstone, massive and conglomeritic. Seen	30
	8.	Concealed	55
482′	9.	Middle Kittanning coal (No. 6, Tuscarawas)	3

The elevation above Lake Erie assigned to the Upper Freeport coal is slightly in excess of the true measure, as the coal seam which we use as a base has been carried downwards somewhat by the dip, before it comes to be used in the new section, but the true elevation is not less than 590 feet above Lake Erie.

On the Rhinehart farm, the distance from the Middle Kittanning coal (No. 6 of Tuscarawas) to the Upper Freeport coal is 130 feet. On the Creighton farm, the same interval measures 142 feet.

The Upper Freeport limestone is found at points without number at this same general elevation. It is frequently burned into lime for local supply.

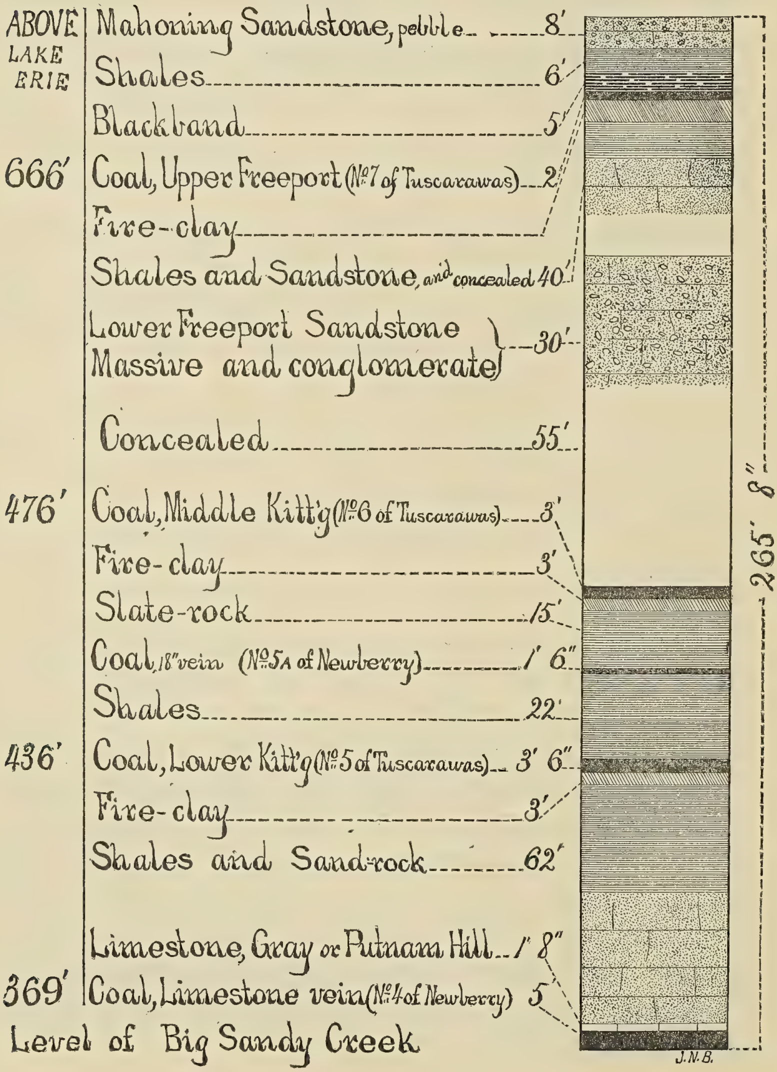
The Lower Freeport sandstone, No. 7 of the previous section, becomes an element of great importance in all of this part of the country. It is quite coarse, and at times even conglomeritic throughout Stark, Tuscarawas, Holmes, and Coshocton counties, and this fact has helped to the wrong identification of it with the Mahoning sandstone. The latter stratum is also distinctly conglomeritic throughout this same region. Where the Lower Freeport sandstone has been counted the Mahoning, it has been found necessary to give a new name to the true Mahoning sandstone. This is called the Stillwater sandstone in the valley of the same name. The fact that the true Mahoning sandstone is more decidedly a conglomerate than the Lower Freeport sandstone, is remarked by Newberry in vol. II, p. 153.

The Lower Freeport sandstone has throughout this region frequently a pinkish or reddish tint, which is quite characteristic.

The blackband coal of the last and previous sections is Coal No. 7 of Newberry, wherever he counts the Middle Kittanning coal No. 6, but it is clear that the No. 7 of Magnolia is one and the same seam with the No. 6 of Rochester. Both hold the same relations to the series in every

FIGURE XV

MAGNOLIA SECTION



particular. Both are at substantially the same elevation above Lake Erie, and more than this, the whole section can be carried along through an open valley without a break or interruption of any sort from point to point.

Precisely the same line of facts will be shown to exist in several other fields to which this confusion of numbers has reached.

The Magnolia section, as now extended, becomes so full and satisfactory that it is reproduced in the preceding diagram, Fig. XV.

Following still further to the southwestward the line of the Cleveland and Pittsburgh Railroad, we reach Mineral Point and Zoar Station, localities that must always be regarded with interest in Ohio Geology, on account of the use made of the sections which they severally furnish, by Newberry, in his arrangement and classification of our Lower Coal Measures. The series shown in this general district is unusually full and interesting.

Its lowest portion is found at Zoar Station, where the Lower Mercer limestone is found occupying the bed of the Connotton. This stratum cannot be well seen here, except at low stages of water, but it is very conspicuous in all of the county to the westward. Its coal, No. 3 of Newberry, is of little value in this part of the State.

The Upper Mercer limestone is more conspicuously shown at Zoar Station than the Lower Mercer. It bears a block or "rock" ore, which is sometimes dug to a small extent, and it covers a coal seam which is more frequently of mineable thickness than the Lower Mercer coal. It is No. 3*a* of Newberry. The limestone is quite uncertain, but the coal almost always marks the horizon. Forty feet above the Upper Mercer limestone, or 70 feet above the Lower Mercer, the Gray or Putnam Hill limestone is found in the railroad cut.

The section in its details is as follows:

Above L. E.			Feet.
361′	1.	Putnam Hill limestone	3
	2.	Coal—Brookville (?), No. 4 of Newberry	1
	3.	Fine grained shale	5
	4.	Sand-rock	5
	5.	Shale	5
	6.	Coal—Tionesta (?)	½
	7.	Sand-rock	23
	8.	Shales with "rock" ore, 1 to 4 ft	1

320′	9.	Upper Mercer limestone	2
	10.	Upper Mercer coal, ½ to 3 ft.	2
	11.	Fire-clay and shales	27
289′	12.	Lower Mercer limestone	2
	13.	Lower Mercer coal.	

The remainder of the section has been so thoroughly worked out and described by Newberry in his report on Tuscarawas county (vol. III), that it is not necessary to describe it here in detail. The order and the measurements which he reports can be adopted without material change.

The Lower Kittanning or Mineral Point coal, No. 5, lies about 60 or 70 feet above the Putnam Hill limestone.

The Middle Kittanning or Pike Run coal, if the seam shall be named from the area of its best development and largest production in Tuscarawas county, No. 6 of Newberry, is in this region 40 or 50 feet above the Mineral Point coal, and a thin seam is often found between the two.

At 120 to 130 feet above the Pike Run coal, the blackband or Upper Freeport horizon is reached. Coal, clay and limestone all occur in characteristic development throughout the region.

The Lower Freeport coal is irregular and uncertain, but it is frequently seen, as is also its limestone. The Lower Freeport sandstone, in its conglomeritic phase, makes a prominent element in all sections here. The Mahoning sandstone is also conspicuous and well marked.

In other words, the section found in the Connotton and Tuscarawas valleys is in all respects identical with the section followed down the Big Sandy.

But the same cannot be said of all of the interior territories. The promising coal field now in process of development in the Connotton Valley rests under the ambiguity of the duplicated numbers, but it will be easy to show that its No. 6 is the seam of that name to the southward, or in other words, the Upper Freeport coal. Its position, so far from the margin of the coal field, is enough to show that the Kittanning coals could not appear there except as a result of reversed dip or other considerable irregularity. There are low anticlinal axes traversing the field, it is true, but there is no such irregularity as the presence of the Kittanning coals would require. The Dell Roy and Sherrodsville coal is without a question the Upper Freeport coal.

To make this apparent, the series will be traced from Zoar Station up the valley of the Connotton to the field now under consideration.

The Connotton, like all streams that flow against the general trend of the drainage, has but little fall. A dam of serviceable height for milling purposes, anywhere in its lower courses, sets the water back for several miles. Given the elevation of the stream at any point, it is easy to trace its rise or fall by means of these long pools.

At Zoar Station, Coal No. 3 of Newberry, the Lower Mercer, is at the level of the stream, and the Kittanning coals are approximately 130 and 175 feet above it. The elevations of the same seams above Lake Erie would be as follows:

Middle Kittanning or Pike Run coal	475 feet.
Lower Kittanning or Mineral Point coal	430 "
Lower Mercer or Blue Limestone coal	300 "

At New Cumberland, the upper of these seams is largely worked on the farms of Thomas Scott and others. As to the identification of the coal there is no question. It holds the same relation to the black-band horizon, which becomes the main guide in this region. The Scott coal is about 60 feet above the valley of the Connotton, or about 380 feet above Lake Erie. This shows its dip to be about 15 feet to the mile in a southeastward direction, which is altogether normal. The Mineral Point coal is followed with it up the valley, being opened at numerous points. The last mine that deserves the name is found near the mouth of the Indian Fork of Connotton, on the farm of John Tate, section 22, Warren township. The entry is 15 feet above the valley of Indian Fork, which is here at about the level of the Connotton. The Pike Run coal (Middle Kittanning) occurs 30 feet above it, but it is thin. The interval between the coals is filled, as usual, with shales containing many nodules of carbonate of iron, dark-blue and fine grained. The massive balls of fossiliferous limestone that are found at the Pike Run mines above the coal, and which are very characteristic, appear also at the same horizon here.

At Moughimon's Mills, in the valley of Connotton, a mile above the last named point, the Mineral Point coal has come down to the level of the stream. It has been opened here and worked in a very small way. The coal is 2 feet thick, hard, bright and excellent. The shales above it are in all respects characteristic. At 32 feet above the

lower coal, the Middle Kittanning coal is found for the last time in this field. It has been mined here in years past. It is from $2\frac{1}{2}$ to $3\frac{1}{2}$ feet thick, and the quality is reported as fair, but the roof is poor and mining has therefore been abandoned. It is 363 feet above Lake Erie at this point.

Crossing the county line into Carroll county, we find within $1\frac{1}{2}$ miles of Moughimon's Mills, the Dell Roy coal opened and worked in an unbroken chain of mines. The first that we reach is the Bartholomew coal bank. It is 108 feet above Connotton or 446 feet above Lake Erie. The Kittanning coals have been carried below the bed of the creek by the dip which we have thus far followed.

The relations of the Pike Run coal to the Dell Roy coal, both of them known as No. 6 in the State series, can be seen by the foregoing facts. The Kittanning coals, viz., the Mineral Point and Pike Run, have fallen to the level of Connotton at the Carroll county line. The Dell Roy coal at its first appearance in this line of sections is 108 feet above Connotton, and more than this distance above the Middle Kittanning coal.

The Lower Freeport coal is found at Dell Roy, 25 feet below the main seam. It is but 18 inches thick, and is described as highly cementing in character.

This section is seen to confirm in all respects the conclusions drawn from the coals of the Sandy Valley and Columbiana county.

It may be added that the Freeport horizon is further attested by its limestones which almost constantly accompany the coals.

The Upper Freeport coal at Dell Roy is about 100 feet above Connotton water. The entry of Empire Mine No. 2 is 459 feet above Lake Erie. The seam falls slowly to the southward, as can be seen by the closely connected openings up the valley of the Connotton. At Sherrodsville (New Hazelton) the coal is 409 feet above Lake Erie. At the point above Sherrodsville where the Wheeling and Lake Erie Railroad crosses the Connotton, the coal is 397 feet above Lake Erie. The Lower Freeport coal is also opened here at 51 feet below the upper coal.

The Upper Freeport coal has been worked at Smith's Mills, 2 miles further up the stream, and on every farm in the interval on the east side of the creek. It lies nearly level in the direction of the valley for a few miles. It is worked quite extensively at Leesville (Leesburg), and attains its highest quality here. At Bowerston it is mined for local use,

at 370 to 380 feet above Lake Erie. A boring lately made here shows the Lower Freeport coal in good development from 50 to 60 feet below the Upper coal. The thickness of the seam, according to the affidavits of the drillers, was 5 ft. 2 in.

The coal mined at Bowerston can be followed to the westward. It runs under the divide of Tunnel No. 10, on the P., C. and St. L. Railway, soon after the station is left, but it emerges promptly on the western side of the tunnel near mile post 86. It has been mined here on the Bell farm, 15 feet below the railroad, where numerous openings are shown. On Jacob Wyandt's farm, the coal has been largely worked 22 feet below the railroad. The seam is here fully 4 feet thick and of the usual quality. It is also worked for shipment on a small scale at Reed's bank, still further west. At Clark's farm the Lower Freeport coal has been worked. It lies 54 feet below the Upper seam, and is said to be 3 feet thick, but no entries are now open. The Upper coal is worked on the Patterson tract still further west, and also at the Stoner bank, where it has risen to 43 feet above the railroad. The last point where it is mined in this field is at the Wesley Foster bank, 1 mile west of Philadelphia Road. It is here about 60 feet above the railroad.

Two miles further west the Dennison coal is reached as it first rises from above the railroad grade. Its elevation above Lake Erie is here 275 ft., while the Upper Freeport coal at the Foster bank cannot be less than 340 feet above Lake Erie. This point is about 6 miles west and 2 miles south of Bowerston.

The Dennison coal is without doubt the Middle Kittanning or Pike Run seam, and thus the line of sections now followed is seen to furnish a new demonstration of the order of the coal measures, so far as the Freeport and Kittanning horizons are concerned. The conclusions reached from these observations are identical with those already established in other parts of the field, but nowhere does the true order come out in clearer light. The leading facts may be thus recapitulated:

The Dennison coal (Middle Kittanning) falls below railroad grade just east of Dennison. One and a half miles to the eastward, the Upper Freeport coal is found 60 feet above railroad grade at that point, or about 100 feet, dip being included, above the Dennison coal. The seam can be followed from this first opening by a constant succession of mines to Bowerston and Leesburg. Throughout this territory it has been

styled Coal No. 7, but the same seam becomes Coal No. 6 at Sherrodsville, Dell Roy and Carrollton. Traced down the Connotton Valley, it is found in the border hills on the Bartholomew farm, 1 mile below Sherrodsville, 108 feet above the valley. Two miles below this point, at Moughimon's Mills, the Kittanning coals are both found, in altogether normal relations, the Lower seam being at the level of the stream. From this point they are followed in clear and definite sections to Zoar Station and Mineral Point.

To these same localities the general series has been followed, as it will be remembered, from the Pennsylvania line. From Zoar Station to the southward and westward, the series has been traced without interruption or question, so far as the main elements are concerned, through the deep valleys of the Tuscarawas and the Muskingum to Zanesville. Through all of this district, Newberry's Tuscarawas county section applies without essential modification, and we could pass at once across the three counties that occupy the interval without losing our hold on the series, but it will be well to give a few typical sections that occur here.

One digression, it is, however, necessary to make. The Cambridge coal field is one of the most important of the State, and its series rests to some extent under the ambiguity of the double numbers. It has been identified by Stevenson as No. 7 of Newberry's series in Tuscarawas county. This refers it to the Blackband or Upper Freeport horizon, and here, as will be clearly shown, it belongs.

The district can be reached most advantageously by the line of the Wheeling and Lake Erie Railroad, formerly the Cleveland and Marietta Railroad, which leaves the Tuscarawas Valley at New Comerstown.

At this last-named place, we find the following section. It extends from the Lower Mercer limestone, which is shown at Suydam's Lock, to one of the coal banks that is worked for the supply of New Comerstown:

		Ft.	In.
1.	*Coal*—Middle Kittanning, Pike Run, No. 6	2	9
2.	Fire-clay	5	
3.	Interval concealed	58	
4.	Limestone—Putnam Hill	2	
5.	*Coal*—Brookville, Gray Limestone coal, No. 4, etc	0	10
6.	Interval concealed, with sandstone, heavy bedded, at base	37	6
7.	*Coal*—Tionesta or Sandstone seam (3*b*)	1	
8.	Shales	4	

		Ft.	In.
9.	Limestone (flinty)—Upper Mercer	3	
10.	*Coal*—Upper Mercer, No. 3*a*	0	6
11.	Interval concealed	21	
12.	Limestone—Lower Mercer, Zoar or Blue	3	
13.	*Coal*—Lower Mercer, No. 3	0	10

The section needs but little remark. The Tionesta coal No. 8 is not usual in this immediate neighborhood, but it is one of the regular seams of the district. The Lower Kittanning or Mineral Point coal is wanting for quite an area about New Comerstown, and the interval between the Putnam Hill limestone and the Middle Kittanning coal is somewhat smaller than is generally found.

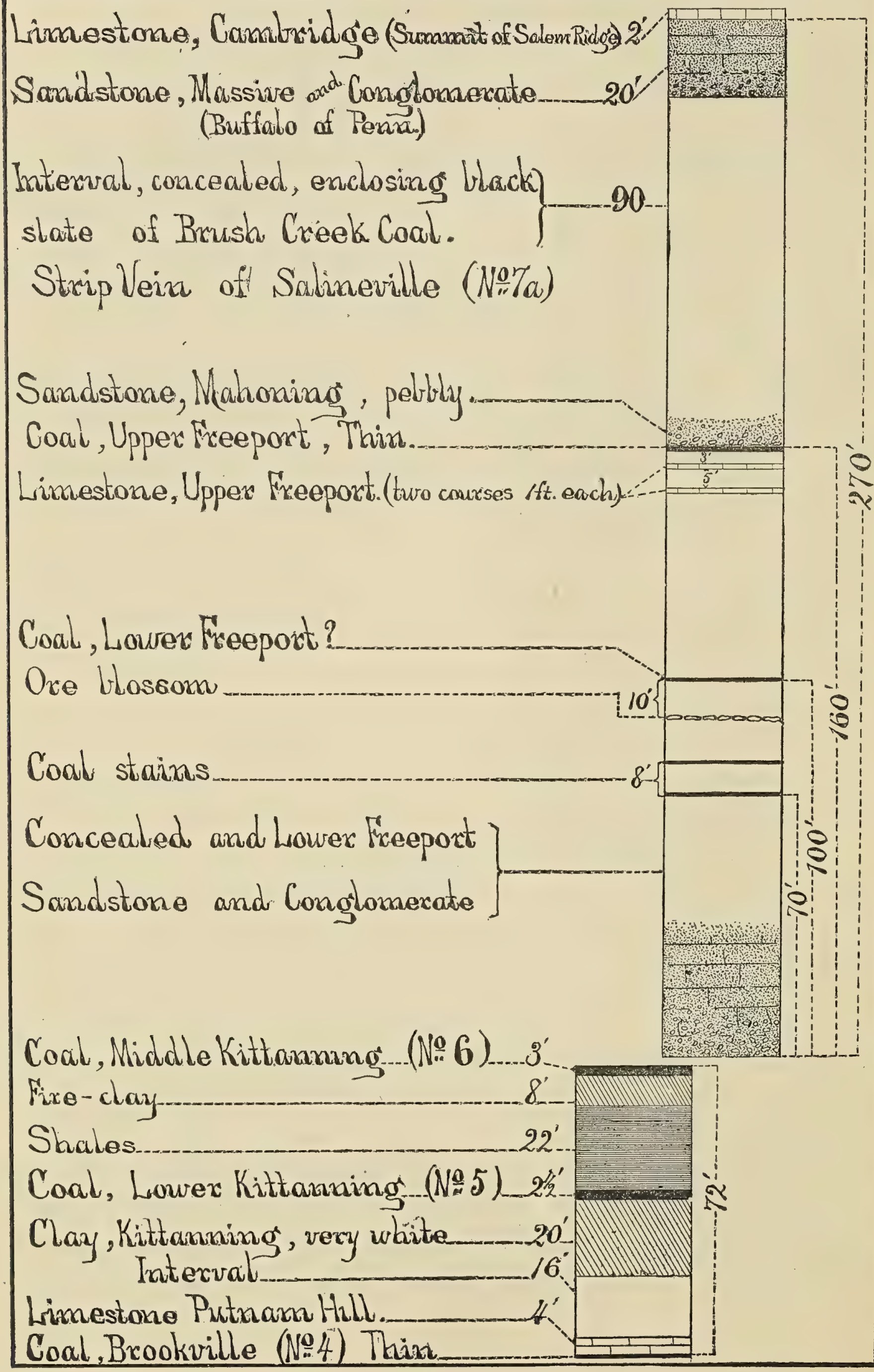
Following the railroad southward from the Tuscarawas Valley, this last-named coal seam is shown in the approaches to Tunnel No. 3, and is worked in numerous small mines along the line. In particular, it is opened by John Booth in the neighborhood of Bird Run Station. Several borings have been made here, and all strike the Putnam Hill and Lower Mercer limestones at the same intervals found on the north side of the divide. Furthermore, we reach a valuable deposit of blackband ore within a mile or two of the station. The section, as thus completed, is as follows:

	Ft.	In.
Blackband ore (7 feet maximum)	5	
Coal—Upper Freeport, Blackband seam	1	3
Interval concealed	140	
Coal—Middle Kittanning, No. 6	3	
Interval concealed	63	
Limestone—Putnam Hill, struck in drill-holes.		
Interval	70	
Limestone—Lower Mercer, struck in drill-holes.		

A considerable deposit of black slate and coal was found about 80 feet below the Lower Mercer limestone in several drill-holes in this immediate neighborhood. This deposit, which was counted as the Briar Hill or Sharon coal, by the drillers, will be considered in a subsequent chapter.

We have now reached the streams that drain to Will's Creek, and by means of the tributary valleys and the main valley, we can advance without interruption to the Cambridge coal field. Like the Connotton, Will's Creek is a stream flowing against the general trend of the drain-

FIGURE XVI
SECTION AT KIMBOLTON GUERNSEY COUNTY.



age, and, like it also, it has a very slow descent, the average fall having been found to be not more than 1 foot to the mile.

We have already recovered the section that we left on the Tuscarawas side of the divide, in its integrity. The Putnam Hill limestone is the base of the new section, and the Upper Freeport coal its summit. The limestone is found near the lowest level of the valleys. Its last occurrence is one mile above Kimbolton (Liberty), on the J. S. Frame farm, section 24, Liberty, where it has been quarried and burned for lime in past years. Its coal is below it here, but it is thin and worthless.

The Lower Kittanning coal takes its place again in some of the sections, and the interval between the Putnam Hill limestone and the Middle Kittanning coal is somewhat increased. The Kittanning clay is also well shown beneath the Lower coal. As to the Middle Kittanning coal, everybody knows its place and its character. It has been opened and worked on every farm without exception for a number of miles in the main valley.

The section which begins at Kimbolton with the Putnam Hill limestone can be carried, in the high ridge that lies south of the town, (the New Salem Ridge), up to the Cambridge limestone. This is a new element, but one that will be found almost indispensable to our safe advance to the southward. The Kimbolton section becomes very valuable by reason of the fact that it embraces these two characteristic elements. It is shown in the accompanying diagram, Fig. XVI:

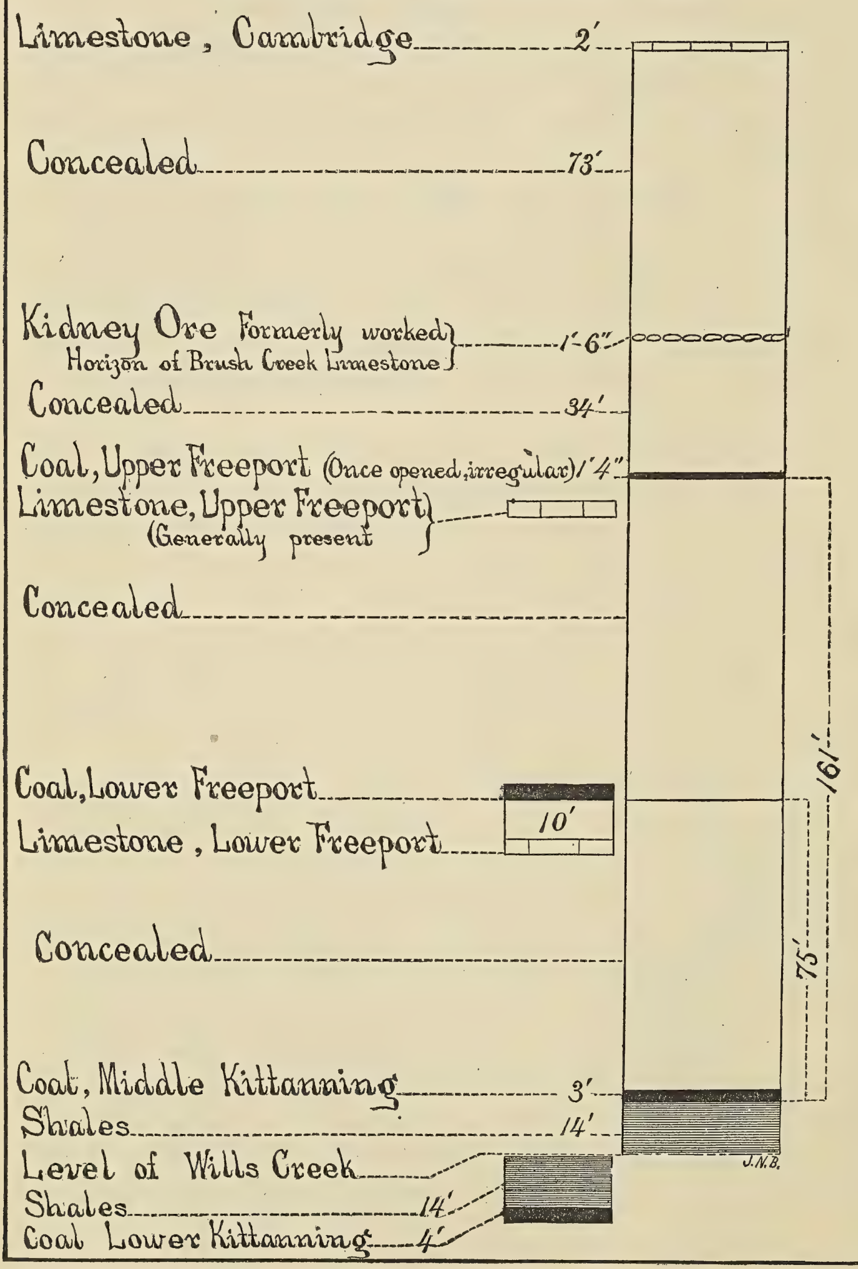
The Lower Freeport coal and the Kittanning clay were both found in a shaft sunk by Hon. T. S. Luccock near his residence.

The upper portion of the section was measured in the Salem road, southeast from Kimbolton, beginning with the Middle Kittanning coal, as opened on the James Gibson farm, section 22, Liberty. The Cambridge limestone occurs almost everywhere along the Salem ridge, section 1, Liberty, extending as far as the Henry McCartney farm to the eastward, and southward to Cambridge with but few interruptions. It was mistaken by Stevenson in this part of the county for the Crinoidal limestone, which it resembles in some of its phases. The Crinoidal limestone belongs fully 100 feet higher in the scale.

The Gibson coal, which makes the base of the upper section, is below the level of high water of Will's Creek. The seam can be followed to the south line of Liberty township, where it goes under the

FIGURE XVII

SECTION AT BROOM'S SALT WORKS, LIBERTY TOWNSHIP, GUERNSEY CO.



creek. It has long been worked in sections 18 and 19 for the manufacture of salt, at both Warden's and Broom's (formerly Ferbrache's) Salt Works. It lies 15 or 20 feet above the level of the creek in all of the mines in this neighborhood. The Lower Kittanning coal has been reached by Robert R. Miller in a shaft on his farm, section 12, and also by J. M. Warden on section 18. The interval varies from 28 to 33 feet. The character of the coal in Warden's shaft is excellent. In early days this coal was pried out of the creek bed at Miller's Ford.

The Middle Kittanning coal all through the valley is known as the "Middle Vein," and the Lower Kittanning coal as the "Lower Vein." The term "upper vein" is applied to the Lower Freeport or Upper Freeport indifferently, the latter being worked in far the largest number of instances. On Robert R. Miller's farm we find a short though excellent section. It is as follows:

	Ft.	In.
Coal—Lower Freeport, formerly mined in small way..	1	6
Fire-clay and shale	10	
Limestone—Lower Freeport..	1	
Concealed	65	
Coal—Middle Kittanning No. 6..	3	
Fire-clay, shale and nodules of ore	28	
Coal—Lower Kittanning (in shaft), reported to be.....................	4	9

At Broom's Salt Works, on the east side of the creek, a long and valuable section is found. It may be made to include the Lower Kittanning and the Lower Freeport coals also, as both are found in the immediate neighborhood, though not recognized at this very point. The section is seen in Fig. XVII.

It will be seen that this section almost duplicates the Kimbolton section. By the two, the following facts are established, viz.: (1) the interval between the Middle Kittanning and the Upper Freeport coals is here about 160 feet, an increase of 20 or 30 feet from the Tuscarawas county sections; (2) the Cambridge limestone lies 110 feet above the Upper Freeport coal; (3) the Upper Freeport coal is no longer capped with blackband. The disappearance of this last-named element is not abrupt. At Kimbolton, on the farm of Joseph Proctor, section 22, Liberty, the black shale above the coal has thin courses of genuine blackband ore, but the aggregate is not large enough to repay working. Similar facts are found throughout the vicinity.

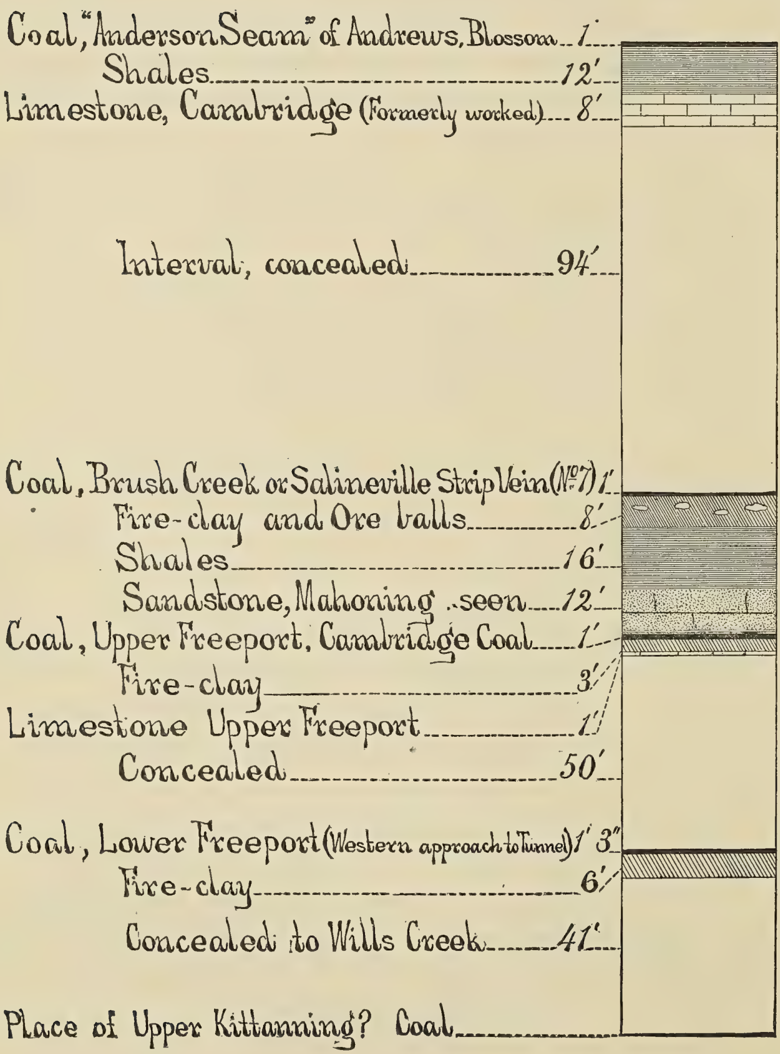
A thin coal seam that comes in between the Middle Kittanning

coal and the Lower Freeport horizon does not appear in either of these sections, but it is quite frequently found in the neighborhood. It has been opened at Warden's Salt Works, and it is worked on a small scale at Oldham's, 2 miles below Cambridge. The vein, though thin, is

FIGURE XVIII

SECTION AT CAMBRIDGE.

TUNNEL HILL.



counted of exceptionally good quality. This appears to be the seam that was struck near the level of Will's Creek at Morton's Mills, in Cambridge, but a somewhat greater thickness is reported here. It may be provisionally identified with the Upper Kittanning coal of Pennsylvania.

The two limestones that are found in the upper portions of the last two sections, viz., the Cambridge and the Upper Freeport, serve to guide us as we advance to the southward. The Cambridge limestone is unmistakable when its stratigraphical place is taken into the account, and the same may be said of the Upper Freeport. If either were found alone in a section, without other elements to indicate the order, it would be possible to mistake the Cambridge sometimes for the Ames, and the Upper Freeport for the Lower Freeport limestone, but in such sections as are here exposed there is no difficulty in holding the order with the same assurance that visible continuity would inspire.

Both limestones come into the section that is found at Cambridge, with many other elements.

In the hill just west of town, that is pierced by the tunnel of the Baltimore and Ohio Railroad, we find a clear and comprehensive section. It is represented in Fig. XVIII.

Four coal seams are found in the Tunnel Hill section. The upper one is a persistent bed in the Barren Measures, through several counties at least. It is the Norwich coal of Stevenson, and the Anderson coal of Andrews. It is frequently found 30 inches thick ,and of fair quality. There has been much uncertainty as to which of the three lower coals of the tunnel section represents the Cambridge coal, if any one of them marks its horizon. In the light of the measurements here recorded, and the various elements that are shown in the section, the question becomes an easy one, and only one answer is possible. The middle seam of the three is certainly the Cambridge coal. It lies 132 feet below the Cambridge limestone, it is true, instead of 110 feet, as in the last two sections recorded, but all the intervals expand slowly to the southward, and every fact agrees perfectly with this explanation. The Upper Freeport clay and limestone both appear below the coal in thoroughly characteristic form. The Lower Freeport coal is seen at the proper interval below, and the Brush Creek coal at the proper interval above it. This last-named seam might have been included in many of the sections between this point and the Pennsylvania line.

The chief difficulty has been that the Cambridge coal exists in fine development at short distances, in almost all directions, and the conclusion that one of these thin and worthless beds must be taken for its representative here has been an unwelcome one. But the Upper Freeport coal is everywhere unsteady in volume, and there is no large territory of it without many interruptions and "wants."

The same section can be found in the hill directly south of the town. The Cambridge coal has been opened here 18 inches in thickness. The interval from the coal to the Cambridge limestone is 137 feet at this point; the coal is about 100 feet above Will's Creek.

Cambridge is situated at the axis of one of the low arches that traverse our coal field. All of the beds dip gently to the east and west. The true direction of the dip is probably southeast and northwest, but the valleys are so cut as to show the east and west elements of it most conspicuously. The coal, which, as has been said, is 100 feet above the creek, comes down to nearly the creek level at Cassell's Station, 5 miles westward, and to the same level a few miles east of Cambridge.

The Upper Freeport coal (Cambridge seam) exists in fair development at Cassell's Station. For 30 years it has been mined for local supply on the Farrar farm, where it is scant 3 feet in thickness. On the adjoining farm of Steele, Lanfesty and Ringer, the coal has been recently opened, and a peculiarity of the seam through a considerable amount of adjacent territory is well displayed. The seam is here doubled, showing the following structure:

	Ft.	In.
Sand-rock, Mahoning, pebbly.		
Black and blue shales, with bands of heavy ore (2 to 6 ft.)	2	
Coal	2	9
Fire-clay, hard	1	4
Coal, heavy and impure	2	

This marked feature helps greatly in identifying the seam to the northward. It is found in a number of mines in Liberty township, and has aided in the identification of isolated exposures.

The limestone is due near the level of the lower coal. *It may be replaced by this lower bed.*

The Cambridge limestone is found at a proper elevation above the coal. The section is as follows:

	Ft.	In.
Limestone—Ames (?), reported.		
Concealed	68	
Coal—Anderson seam	2	6
Shale, red	10	
Limestone—Cambridge	4	
Fire-clay and red shale	15	
Concealed	20	
Sand-rock, heavy (seen)	25	
Black slate, highly bituminous with marine fossils	5	
Coal—Brush Creek, Salineville Strip Vein	1	4
Concealed	25	
Sandstone—Mahoning, Conglomerate	26	
Black slate, with seams of iron ore	6	
Coal—Upper Freeport	3	
Fire-clay	1	4
Coal	2	
Limestone—Upper Freeport, in adjoining farms.		

The Cambridge limestone is here 127 feet above the Cambridge coal.

On the east side of town, along the valley of Leatherwood Creek, and on the line of the Baltimore and Ohio Railroad, there is found one of the finest and most largely worked developments of the Cambridge coal. A number of large mines are in operation here. At Wm. Norris's mines, section 4, Center township, the following section was obtained. It can be duplicated on all the adjoining farms, so far as most of the elements are concerned :

	Feet.
Limestone—Ames, Crinoidal	3
Interval, mostly concealed	107
Coal—Anderson, blossom.	
Shales	10
Limestone—Cambridge (universal)	4
Interval, concealed	115
Sandstone—Mahoning (seen)	20
Shale, blue	1
Coal—Upper Freeport, Cambridge seam, 3 to 6 ft	4
Limestone—Upper Freeport.	

The interval between the Cambridge limestone and the Cambridge coal here measures 136 feet. Throughout the district occupied by this seam, this is the usual interval. Sections involving all of these elements in the same order and relations can be multiplied indefinitely, but those

already given are conclusive and fully confirm the reference of the Cambridge coal to the Blackband horizon, as made by both Stevenson and Andrews in their reports upon the district.

The section has been extended downwards by the records of the salt wells bored in this same district. Andrews quotes the record of salt well No. 2, on the Scott farm (Geol. of Ohio, vol. II, p. 534).

This record is introduced here and interpreted in accordance with the general section that has been traced directly to this point from the Tuscarawas Valley. It is as follows:

		Ft.	In.
1.	Level of the Cambridge (Upper Freeport) coal.		
2.	Soil, etc.	18	
3.	Gray sand-rock	32	
4.	Not known	10	
5.	*Coal* (Lower Freeport)	1	6
6.	Fire-clay (Lower Freeport)	3	
7.	Limestone (Lower Freeport)	1	6
8.	Soapstone	6	
9.	Shale and fire-clay	26	
10.	Black slate	10	
11.	Shale	12	
12.	*Coal* (Upper Kittanning?)	0	10
13.	Soapstone	40	
14.	*Coal* (Middle Kittanning?)	1	2
15.	White fire-clay	20	
16.	Blue sandstone, oil rock	44	
17.	Black shale	31	
18.	Limestone (Putnam Hill)	0	11
19.	Shale	14	
20.	Iron ore, very hard	1	6
21.	Shale	69	
22.	Hard black rock	6	
23.	Shale	80	
24.	Stratum charged with sulphuret of iron	3	
25.	Interval not recorded	215	7
26.	White sand-rock	40	

The intervals will be seen to be as follows: From Upper Freeport coal to Lower Freeport coal, 60 feet; from Lower Freeport coal to Upper Kittanning (?) coal, 58 feet, and to Middle Kittanning (?) coal, 99 feet; from Middle Kittanning (?) coal to Putnam Hill limestone, 96 feet.

Another obvious construction of the two lower coals is to count them the Middle and Lower Kittanning coals, respectively, instead of Upper

and Middle Kittanning. The 20 feet of white clay would then be the Kittanning clay, but the limestone, No. 18, is the surest element of the section, and this makes the first interpretation the more probable one. By comparing it with the Kimbolton section, Fig. XVI, it will be found to agree very closely.

The Cambridge coal field is thus seen to be the third important development of the Upper Freeport seam in Ohio, the Salineville, and the Connotton Valley fields having been already referred to this horizon.

Coal Seams of the Lower Tuscarawas and Muskingum Valleys.

Returning from this detour to the work of tracing the westward extension of the general section thus far followed, we can assure ourselves, as has been already said, of the integrity and unbroken continuity of our series in this direction, by the measurement of a few well-selected intervals. Even these are not essential to the establishment of such continuity, for no question has been raised as to this fact. Every geologist that has worked in the field has been obliged to accept and adopt the universal belief of land-owners and coal miners throughout the territory, that the Pike Run coal, the New Comerstown coal, the Coshocton coal, the Rock Run coal, the Upper Dresden coal, the Upper Zanesville coal, are all one and the same seam. It is the No. 6 of Newberry in the Tuscarawas Valley, and the Middle Kittanning coal of the Pennsylvania series. In fact the mines and country coal banks opened in this seam, throughout this territory, effect as close an approximation to visible continuity as we can find in any like part of the Lower Coal Measures.

A few sections will here be introduced, covering and fairly representing this wonderfully steady portion of the margin of our coal field.

The section at Zoar Station and Mineral Point has been already described in part, but it will be repeated here in connection with the others that are selected. In Figs. XIX and XX the following sections are represented :

XIX. A. Zoar Station and Mineral Point.
B. Lot 30, Dover township, Wm. Swaby's farm.
C. York township, Franz Ankeney's farm.

XX. D. Glasgow-Port Washington Furnace tract.
E. New Comerstown and Bird's Run.
F. Beech Hollow, 2 miles east of Coshocton.

FIGURE XIX

A SECTION AT ZOAR STATION AND MINERAL POINT TUSCARAWAS CO

B SECTION FROM LOT 30 DOVER TWP. FARM OF Wm SWABY TUSCARAWAS CO.

C SECTION AT YORK TOWNSHIP FARM OF F. ANKENY TUSCARAWAS CO.

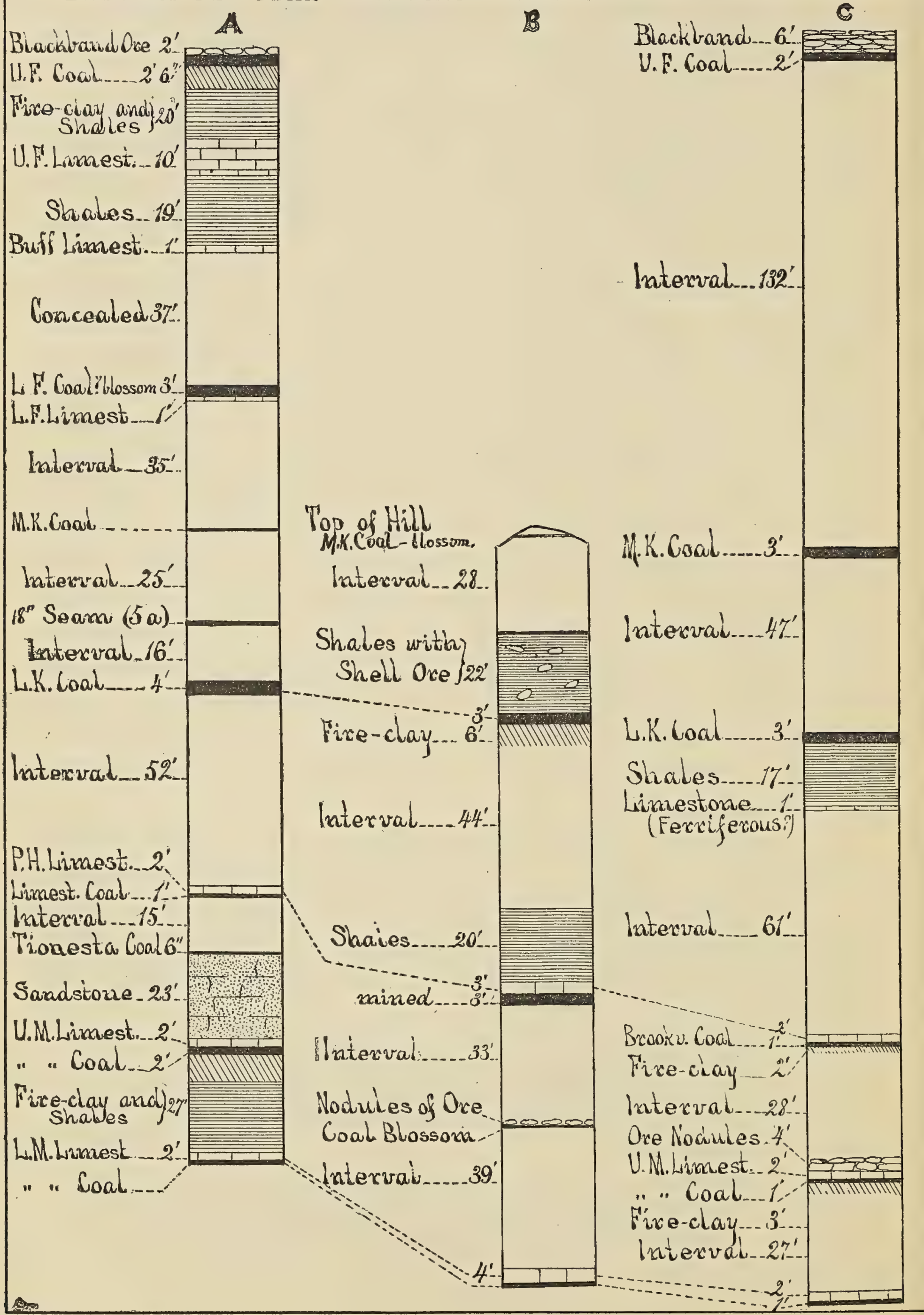


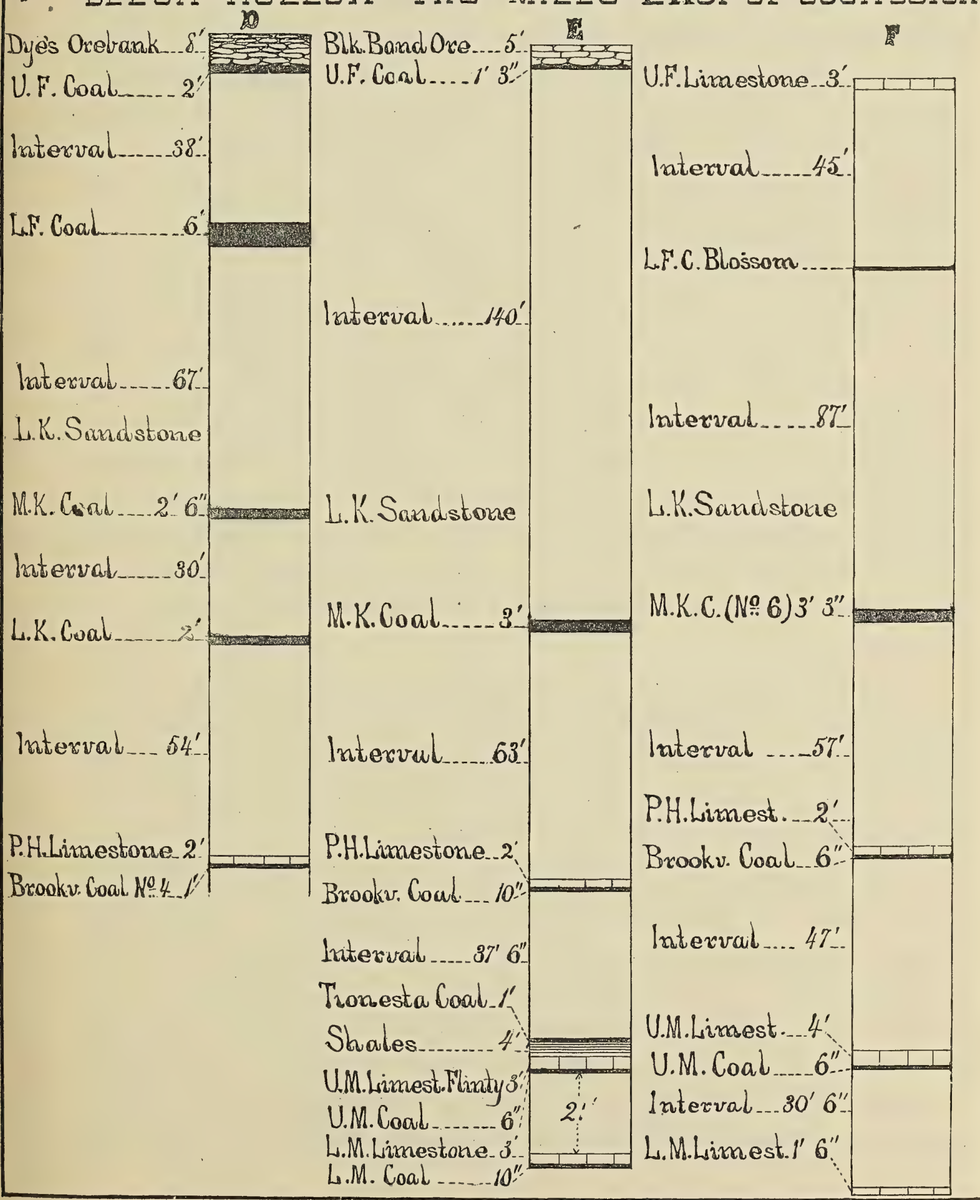
FIGURE XX

SECTIONS IN TUSCARAWAS AND COSHOCTON COUNTIES

D GLASGOW PORT WASHINGTON FURNACE TRACT.

E NEWCOMERSTOWN AND BIRD'S RUN.

F BEECH HOLLOW TWO MILES EAST OF COSHOCTON



It will be observed that the two series of sections are quite unequal in measurement. Section C of Fig. XIX is located at a well-marked boundary in the coal field. From this point westward there is a noticeable diminution in intervals. The leading elements, with the exception of the Lower Kittanning coal, all retain their relative positions, but this last-named seam becomes uncertain. The most decided reduction of interval takes place between the Middle Kittanning coal and the Putnam Hill limestone to the westward.

In section D, a fine local development of the Lower Freeport coal occurs. The seam ranges from 2½ to 9 feet in thickness. It is called No. 6 in the report on Tuscarawas county, in volume III, but the section as given here shows clearly that it is entirely distinct from the Middle Kittanning coal, which appears at its normal interval below.

The present line of sections has carried us through one of the most important mineral districts of Ohio, viz., the Tuscarawas Blackband field. The same order of facts can be observed with reference to this horizon here as at other points. *The blackband lies on the outer margin of the Upper Freeport horizon, while the mineable coal of the same horizon is found in the interior.* The Upper Freeport coal is nowhere throughout this district of value as a source of fuel upon its western outcrops, or where it lies high in the hills. It is only where it approaches its interior boundaries that it gives rise to important mining centers, as at Salineville, at Dell Roy, and in the Connotton Valley, and at Cambridge.

The last section of the list, which was taken near Coshocton, fairly represents the Tuscarawas Valley for the remainder of its course. The valley runs in the direction of the *strike* or level bearing of the strata, and the same elements that appear at Coshocton can be found in almost every ravine between that point and Dresden.

The southward trend of the whole coal field aids in continuing the section down the Muskingum Valley as far as Zanesville. The Lower Mercer limestone and coal make the floor of the Muskingum at the foot of Putnam Hill, while the gray limestone gets its geographical name from this very locality. The Kittanning coals are found here in excellent development, and have long been extensively worked. The Upper Freeport coal, clay and limestone, and also the Lower Freeport coal are all found at their proper level on every side, and the Cambridge and

Ames limestones also continue through the field to re-enforce and confirm the sections built from the elements of the lower coals.

No sections from the Coal Measures of Ohio are better known than those from Zanesville and vicinity. Foster of the first Survey, Newberry and Andrews of the second, have all made frequent use of them, and frequent appeal to them. Andrews gave a name to one of the most widely distributed limestones of the Lower Coal Measures of Ohio from Putnam Hill, opposite Zanesville. The Kittanning coals are familiarly known through several counties as the Lower and Upper Zanesville coals, both of which are largely worked within the corporation limits.

The leading elements are as follows: The Lower Mercer limestone and coal are found, as has been already said, in the bed of the Muskingum at low water, and almost everywhere to the north and west where their horizons are exposed. The Upper Mercer limestone and coal are found, one or both, in most of the sections, but the limestone is, as usual, less reliable than the companion seam below. It is very often replaced by flint. The usual interval is 25 to 30 feet.

The Tionesta coal is shown in probably two out of three sections that cut its horizon, at 5 to 15 feet above the Upper Mercer limestone.

The Clarion? (Lower) coal is represented in many sections by a seam, seldom exceeding 16 inches in thickness, that occurs 15 or 20 feet above the Putnam Hill limestone. It is the No. 4*a* of several localities.

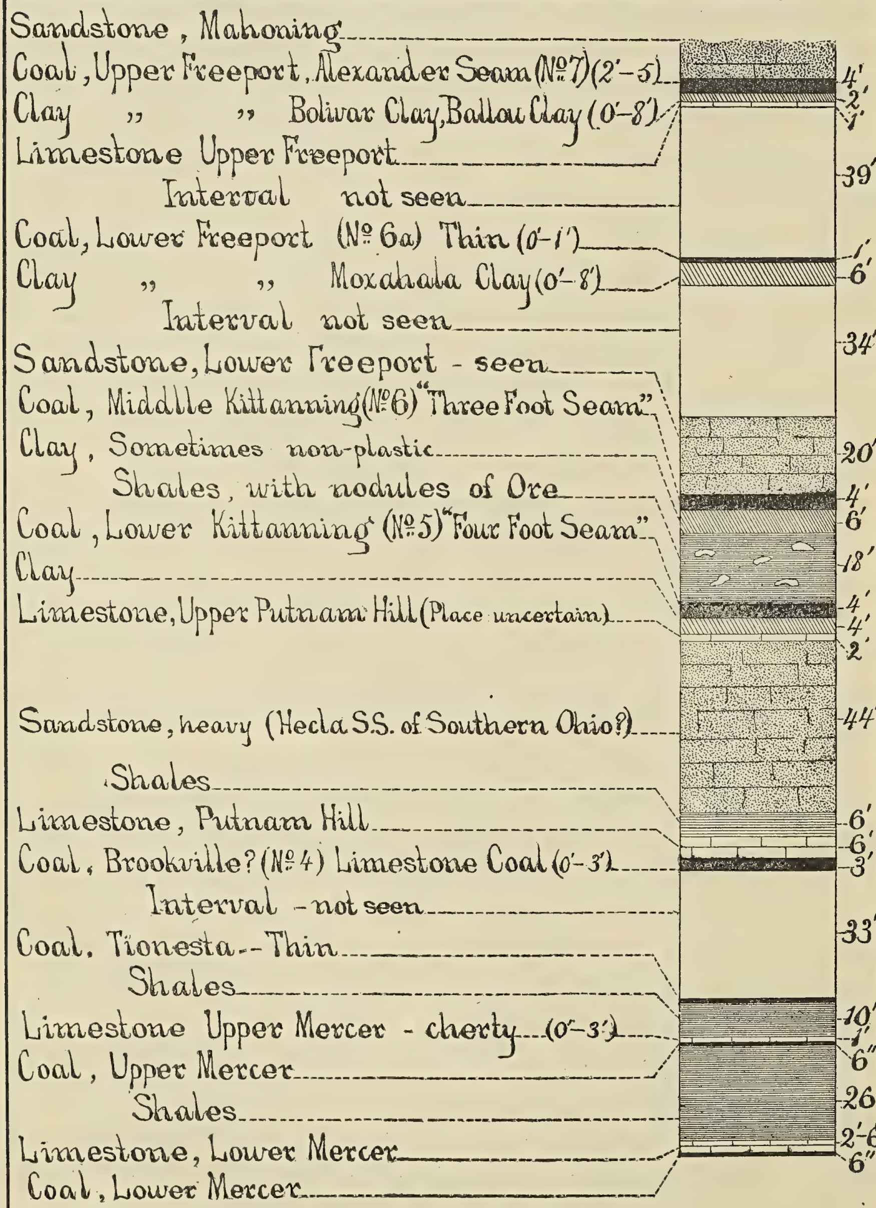
A heavy sandrock comes in between the Lower Kittanning coal and the Putnam Hill limestone in the vicinity of Zanesville. It is quarried quite largely, and furnishes a building stone of unusual excellence. Where it occurs, the interval between the two elements last named reaches or exceeds 60 feet. The Lower Kittanning coal is known as the 4-feet seam throughout this district, and the Middle Kittanning coal as the 3-feet seam, these names agreeing with the common measurements in mines of the several seams. The interval between these coals ranges from 16 to 32 feet. The most common measurement is 28 feet or thereabouts.

The Lower Freeport coal is not unknown, but it is generally too thin to repay working. Its place is 50 to 70 feet above the Middle Kittanning. It carries with it a valuable bed of clay throughout portions of Muskingum and Perry counties, which is known from the locality of its best development as the Moxahala clay.

The Upper Freeport horizon is found about 50 feet above the

FIGURE XXI

COMBINED SECTION FROM ZANESVILLE AND VICINITY.



Lower, or from 90 to 120 feet above the Middle Kittanning coal, No. 6, but it differs from the Lower Freeport in being of great economic value and interest, and in being universally known.

Three of its elements unite to mark the horizon in the vicinity of Zanesville, viz., the limestone, the fire-clay and the coal. No black-band ore is known to occur with the coal in the Muskingum Valley. Contrary to the facts referred to on a previous page, the Upper Freeport coal is here mineable, well on to its western outcrop, and where it lies quite high in the hills. About Zanesville, it is commonly known as the Alexander coal, and it is quite largely worked in Washington, Perry, and other townships. It is always underlain by its limestone, and at Ballou's Salt Works, 6 miles below Zanesville, the Upper Freeport or Bolivar clay has a good development, and is quite extensively worked. It has the same character as at Bolivar, Pennsylvania, and at many points along the line. It is a hard or non-plastic clay, with many green streaks of silicate of iron and alumina diffused through it. It does not attain the very highest quality as it is thus far shown in the workings.

A combined section from Zanesville and vicinity is shown in Fig. XXI. The intervals used are all measured intervals in particular sections. From the Putnam Hill limestone the section is continuous through Mill Creek valley and the Harper coal banks, up to Adam Rock's mine, in the Alexander seam, except that the Lower Freeport seam was found 1 mile to the northward.

One element only in this section needs to be described. It is No. 15, and is designated as the *Upper Putnam Hill limestone.* The exact stratigraphical place of this stratum is not determined. There are but few occurrences of it known, and no one of these has been found in any section in which the Lower Kittanning coal appears. It is about the same distance below the Middle Kittanning coal that the Lower coal should be, and it may occupy the exact horizon of this seam. The best exposure of it is on Putnam Hill, directly above Putnam Station. It is there 27 feet below the Upper Zanesville coal (No. 6). It is a drab limestone, weathering yellowish white. It is fossiliferous, containing a Productus and other marine shells. Quite a heavy deposit of clay occurs in connection with it, and it bears an iron ore. These facts have suggested it as the equivalent of the Ferriferous limestone of Pennsyl-

vania and of Southern Ohio, but its distance from the Putnam Hill limestone below, viz., about 60 feet, militates against this view. It may be noted, however, that this particular interval between the Lower Kittanning coal and the Putnam Hill limestone is longer by 20 or 30 feet than at most other points in this region. If the interval should be shortened to that extent in this case, the reference of the limestone to the Ferriferous would be less objectionable, to say the least.

The Cambridge limestone, in the nearest exposures to Zanesville, is 112 feet above the Upper Freeport coal. Its range is 112 to 132 feet above this horizon. The Ames or Crinoidal limestone is generally about 100 feet above the Cambridge, but the interval is occasionally materially shortened, coming down to 60 feet at Blue Rock and in its vicinity.

The Cincinnati and Muskingum Valley Railroad, running southwestward from Zanesville, keeps nearly on the line of strike of the strata, and thus along its course, the same elements that we have thus far followed, are constantly exposed. The complete identity of the very numerous and excellent sections to be found at Del Carbo, Roseville, McLuney and other points along the line with the Zanesville section, is recognized by every one who has had anything to do with the field in either a scientific or practical interest. The Kittanning coals, in particular, can be followed most directly from point to point, and no question as to their persistence and continuity is admissible. The coals and limestones are largely worked along the railroad line, and country banks complete the connections where mines are wanting.

The intervals change somewhat, mostly in the way of contraction, throughout the region upon which we have now entered. A few typical sections will be recorded here.

At Del Carbo both of the Kittanning coals have long been worked on the large scale for railroad supply. The Putnam Hill limestone has also been mined here quite largely for Moxahala Furnace. The Mercer limestones both occur in their places as soon as these places are reached by the deepening valleys on either side. The immediate series at Del Carbo is as follows:

	Feet.
Middle Kittanning coal, including bone coal (No. 6)	$4\frac{1}{2}$
Fire-clay	4
Shales with iron ore	12
Lower Kittanning coal (0 to 5 ft.) (No. 5)	5
Fire-clay	4
Shales, etc	34

	Ft.
Putnam Hill limestone	4
Interval	28
Limestone—Upper Mercer, flinty	2
Coal—Upper Mercer	1
Interval	23
Limestone—Lower Mercer, in bed of run.	

By passing over the ridge into the deep valley of Jonathan's creek, we drop by rapid descent to the very bottom of the coal measures. The Newtonville limestone, which Andrews showed to be of sub-carboniferous age, makes the floor and walls of the creek for a number of miles. The Lower Coal Measures are shorter here than at any other point in the State, but the series is not shortened by the omission of its leading elements. Almost every stratum that is due can be found here. The section from the level of the creek is as follows:

	Feet.
Coal—Middle Kittanning or Upper Del Carbo seam (No. 6)	4
Interval	20
Coal—Lower Kittanning or Lower Del Carbo seam (No. 5)	4
Interval	38
Limestone—Putnam Hill	4
Coal—thin	—
Interval, including Limestone, Upper Mercer	70
Coal—thin	—
Limestone—Lower Mercer	2
Coal—thin	—
Interval	80
Limestone—Maxville, Sub-carboniferous—(seen)	15
Bed of stream.	

In the neighborhood of Cusaac's Station, and mainly on the farm of Mrs. Phoebe France, the following interesting section is obtained:

	Ft.	In.
Coal—Middle Kittanning (No. 6) (worked)	4	
Interval, covering place of L. Kittanning, which is wanting	36	6
Ore and flint—Ferriferous limestone horizon	1	
Interval	10	
Coal—Clarion Lower (?), "Peacock coal" (opened)	1	4
Interval	10	
Limestone—Putnam Hill	2	
Interval	23	
Ore—red block (local?)	—	
Interval	25	
Limestone—Upper Mercer, with ore	1	6
Interval	25	6
Coal—Lower Mercer, cannel seam, 0 to 3 ft	2	
Level of Jonathan's Creek.		

In this section an interesting feature is the appearance of the Ferriferous limestone at its proper horizon. From this point westward, it can be found in almost all well exposed sections in which it is due, faint at first, but gradually strengthening, its ore increasing more rapidly than the limestone, but both becoming strong and clear elements in southwestern Perry county.

At Roseville, there are extensive potteries which are established upon two beds of clay that belong to the series already discussed. All of the horizons have been developed in this vicinity so as to give excellent opportunities for measurements. The section immediately about Roseville is as follows:

	Ft.	In.
Middle Kittanning Coal, with bone coal (No. 6)	4	6
Fire-clay	4	
Shales wlth nodules of ore	16	
Lower Kittanning Coal (No. 5) (0 to 4 ft)	4	
Lower Kittanning Clay—largely worked	7	
Interval	30	
Putnam Hill Limestone	4	
Brookville ? Coal—Limestone seam—thin	—	
Interval	25	
Tionesta Coal—thin	—	
Tionesta Clay—largely worked	10	

A long and valuable section is found in the Brush creek road that runs eastward from Roseville. The ground rises rapidly and the characteristic Barren Measure strata are soon reached.

The section is as follows:

	Ft.	In.
Coal—thin.		
Interval	16	
Limestone—Ames or Crinoidal	3	
Interval—mostly shales	43	
Limestone—Cambridge	2	
Interval	32	
Coal—Brush Creek of Pennsylvania, Salineville Strip Vein	—	
Shale—red	10	
Shale, etc	28	
Coal—Upper Freeport—"Basin Vein", 0 to 4 ft. (No.7)	1	
Fire-clay	2	
Limestone—Upper Freeport	3	
Interval	20	
Sandstone	15	
Coal—Lower Freeport—thin	—	
Interval—concealed	60	
Coal—Middle Kittanning (No. 6)	4	6

The interval between the Ames and Cambridge limestones at this point is the smallest yet recorded in the State, but both limestones are unmistakable, and moreover, the Blue Rock section, 10 miles to the eastward, shows a similar though not equal reduction of this interval.

The Upper Freeport horizon is very distinctly marked in this neighborhood. On the Ashton, Duval and Cunningham farms, the coal obtains a good development as to thickness and character. It is known as the *Basin Vein*, a name suggested by its capricious and unsteady character. The Upper Freeport limestone is 3 feet thick on the Ashton farm, and is pure enough for the mason's use. It has been burned here on a small scale. It is in every respect characteristic.

The Lower Freeport coal does not fail to leave its mark in every exposed section where it is due, but it is of no value as a source of fuel throughout this immediate region.

Passing westward into Perry county, the Kittanning coals can be followed by openings made upon one or both seams on every farm along the railroad line. At McLuney, at Tague's, and at the tunnel, the coal has been mined for 20 or more years for the general market, mainly from the Middle Kittanning seam.

A few miles south of McLuney Station, on section 16, Bearfield township, Perry county, the Upper Freeport horizon exhibits once more a characteristic product, which has been missed from our sections for the last 50 miles. A valuable deposit of blackband ore has been discovered and quite extensively worked on the Whitlock farm, for Moxahala Furnace. A long and clear section can be obtained from this immediate vicinity. It is as follows:

	Ft.	In.
Red shales.		
Limestone—Cambridge	3	
Interval	50	
Coal—Brush Creek of Pa., Salineville Strip Vein (No. 7*a*)	2	6
Interval	29	
Ore—nodular	1	
Interval	12	
Blackband Ore and Coal, Upper Freeport (No. 7)	3	
Interval	49	
Ore—nodular	0	6
Interval	12	
Fire-Clay	4	
Ore—blue and calcareous	1	
Interval	46	6
Coal—Middle Kittanning (No. 6) (bone included)	4	6

The intervals are seen to be nearly normal, viz., 117 feet from Middle Kittanning coal to Upper Freeport, and 95 feet from latter to Cambridge limestone. The section was taken in two parts, the upper portion coming from the Whitlock farm, where the Cambridge limestone directly overlies the Whitlock ore, and the lower portion being taken from the coal mine opened in the universally known Middle Kittanning seam, on the farm of R. Moore, section 8, Bearfield, and thence up the township road ½ mile to the eastward.

Returning to the line of the railroad once more, we find at New Lexington a section almost, if not quite, as widely known as the Zanesville section already given. The Kittanning coals are styled here the Upper and Lower New Lexington coals. Both are well developed, and both have long been worked. They are separated by an interval of 20 to 30 feet. The Putnam Hill limestone is very conspicuous at New Lexington as a limestone and flint horizon. It is shown in the valley on the northeast side of the town at the level of the railroad.

At 12 to 15 feet above it, a quite persistent coal seam is found. It is seldom more than 16 inches in thickness. It holds the place of the Clarion (Lower) coal, and if numbers are to be provided for all the regular seams on the basis of the system that is now in use, this should be called No. 4*a*, a designation that it has already received to a limited extent.

Within 3 miles of New Lexington the so-called Baird ore is mined quite extensively on many farms. The place is 15 to 30 feet above the Putnam Hill limestone, but the latter element, after having been found persistent through a half-dozen counties, is verging to its extinction. From New Lexington southward it can be followed indeed, but no longer by a bold outcrop, but only by occasional exposures which would be ambiguous in themselves, and which require to be supported by other and better known elements. In other words, the Putnam Hill limestone has now exhausted its capacity of service as a guide, and needs to be interpreted when found, like the obscurer elements that have heretofore leaned upon it.

But the series is not weakened by its diminution or disappearance, for the Ferriferous limestone horizon has been again restored, as a steady and easily recognizable element, and from this point to the Ohio river it is a dominant feature in every sub-division of the field.

In volume III, Geology of Ohio, p. 924 et al., it was demonstrated

that the Baird ore of Perry county is the Limestone ore of the Hanging Rock district. Since that volume was published, there has been great activity in tracing and developing the various coal, ore, and limestone horizons of the Lower Coal Measures through Perry, Hocking and Vinton counties, an activity stimulated by the demands of the new furnaces of the Hocking Valley for these various elements of iron manufacture. The demonstration referred to above has entered into many of these schemes of discovery and development. If there were error or uncertainty involved, it would necessarily have been made apparent in the course of these investigations, but not only does the original line of sections on which this demonstration was established stand unimpugned, but a great number of new and independent facts have been brought out which leave this identity as well settled as any point of like character in Ohio Geology.

Two or three skeleton sections will be given to illustrate the steadiness of the elements that we have been following as they occur in this new field. On the farm of Thos. S. Mains, section 7, Pike township, the following elements were seen in the relations indicated:

	Ft.	In.
Coal—Middle Kittanning (No. 6)	3	6
Interval	26	
Coal—Lower Kittanning (No. 5)	1	
Clay—Lower Kittanning, white	6	
Interval	70	
Flint—Upper Mercer	2	
Interval	5	
Coal—Upper Mercer (0 to 3 feet)	3	
Interval	25	
Limestone—Lower Mercer, bearing block ore	2	
Coal—Lower Mercer, thin.		
Interval	14	
Ore—Block, Junction City ore	1	

At McCuneville precisely the same range is well shown, and here we find the measurements as follows:

	Ft.	In.
Coal—Middle Kittanning (No. 6)	4	6
Interval	30	
Coal—Lower Kittanning (No. 5)	1	
Interval, mostly white clay	15	
Ore and flint—Ferriferous limestone, Baird ore	1	6
Interval	18	

	Ft.
Ore and impure limestone	2
Interval	46
Limestone and flint—Upper Mercer, bearing ore	2
Interval	30
Limestone—Lower Mercer, bearing ore	2
Coal—Lower Mercer, thin.	
Interval	14
Ore—Junction City block ore	1

The McCuneville coal is traced by continuous workings into the *Great Vein* of Shawnee and Straitsville, and this in turn is strictly continuous with the Nelsonville and Monday Creek coal, and thus our section is carried at once to the west side of the Hocking Valley.

There is not only no question but there is really no room for question as to the fact that the upper coal at McCuneville becomes the main coal of the Hocking Valley in its several subdivisions. In other words, the Nelsonville or Straitsville seam is the Middle Kittanning coal. This wide-spread seam here scores its highest mark both as to volume and quality, and forms the central element in the most important coal field of the State.

The Lower Kittanning coal still attends it as a constant companion, but though often of a thickness that would be counted mineable elsewhere, it is so overshadowed by the greater seam above it, that little account is made of it in the Hocking Valley, except as an element in the geological scale.

The Freeport coals have not been mentioned in any of the more recent sections, but simply for the reason that their horizons have not been reached in these sections. The hill east of Roseville is the last point where they were recognized, but they sweep in absolutely unbroken outcrops through all the high grounds. We cannot measure a single section throughout this whole region in which there is any adequate exposure of the strata, without finding one or more elements, especially of the Upper horizon, shown.

Shawnee furnishes a clear and excellent section. Its main elements are as follows:

	Ft.
Coal and blackband ore—Upper Freeport, Iron Point ore (No. 7)	3
Fire-clay and shale	18
Limestone—Upper Freeport, Shawnee limestone, worked largely for furnaces	2
Interval	34

	Ft.	In.
Coal—Lower Freeport, general but thin (No. 6*a*—No. 6*b*)	1	
Limestone—Lower Freeport, Norris limestone	0	6
Interval consisting of—		
Sandstone or shale	25	
Shale (0 to 20)	10	
Coal—Middle Kittanning (No. 6)	10	
Shales, holding Snow Fork Kidney ore	8	
Interval	18	
Coal—Lower Kittanning (No. 5)	3	
White clay	12	
Ore and Limestone—Ferriferous limestone, Baird ore	1	

The Upper Freeport or Shawnee limestone becomes one of the most reliable guides to the geology of the Hocking Valley. It is well-nigh universal in its distribution, and is so well characterized that its outcrop can scarcely be missed.

Passing from Shawnee to the Sunday Creek Valley, we find the same section in substance. As usual, the blackband is on the *margin* of the Upper Freeport seam, while a well-developed coal field lies in the interior. The Bayley's Run coal and the Norris coal, which are one and the same seam, represent the Upper Freeport in this interior development. The Lower Freeport is seldom workable. In fact, no instance is known in which this seam is mined in this region. The Upper Freeport limestone is found about half-way between the Upper and the Lower Freeport coals. The Norris coal, so called, got its name from quite extensive country banks near Millerstown. The Ohio Central Coal Company has developed this region by the opening and working of this seam in the large way. The twin mines, No. 12, are opened on a farm adjoining the Norris lands, and no one can doubt the identity of the coals in these two areas. In the railroad cut above the mine, the Upper Freeport limestone and the Lower Freeport coal are both fully shown, while the Upper Freeport coal is reached directly above. The section here is as follows:

	Ft.	In.
Sandstone—Mahoning.		
Shales over coal (2 to 10 feet)	10	
Coal—Upper Freeport, Norris seam, Bayley's Run	6	
Fire-clay and shale	18	
Limestone—Upper Freeport, Shawnee limestone	2	
Fire-clay and shale, with iron ore	12	6
Sandstone	5	

	Ft.	In.
Coal—Lower Freeport	2	6
Fire-clay—Containing large kidneys of ore, Lower Freeport limestone?	5	
Place of "Great Vein," which is wanting here, usual interval (45 to 60 feet).		

The Norris coal has so long and so uniformly been counted the seam below the Bayley's Run coal, that a few statements in regard to the seam are called for at this point.

Andrews first assigned a place to this seam (Geol. of Ohio, Report of Progress, 1869, p. 119). In vol. III, p. 851, he refers the determination of interval to his assistant, Mr. W. B. Gilbert, by whom a measurement of 46 feet was obtained between the "Great Vein" (Middle Kittanning) and the Norris coal. Having already assigned a place to the well-known Bayley's Run coal, 75 to 100 feet above the main coal, the Norris coal became the middle seam. When numbers were applied to the coals, and the Middle Kittanning become No. 6, and the Bayley's Run coal No. 7, the Norris coal was styled No. 6*a*. This number was afterwards changed to No. 6*b* in my report on the Hanging Rock District, vol. III, on the ground that a regular seam occurs at 25 to 30 feet above the Nelsonville coal, while the Norris coal was counted as coming in at 45 to 55 feet above that seam. Andrews also in his later work seems disposed to give a place to a seam between his Norris coal and the Nelsonville seam (vol. III, p. 851).

Truths and errors are so interwoven into all of these accounts that the disentangling of them would be a tedious task. There is in some parts of the field a thin coal between the Middle Kittanning and the Lower Freeport coals. It is not certain, however, after all that has been written, that this seam occurs in the Hocking Valley field. The varying intervals of the Lower Freeport and the Nelsonville coals may account for all of the facts. The name *Norris coal* has been so unfortunately applied that it will serve geological order to drop it altogether. The facts, as at present seen, are as follows:

The two Kittanning and the two Freeport coals maintain their horizons with great regularity throughout the Hocking Valley coal field. The Kittanning coals are the steadiest of all our coal seams, and the upper of the two is by far the most valuable seam of the Lower Measures. The coal seams of the Freeport Group are exceedingly uncertain and irregular in the large way, but the upper seam gives rise to many fine local developments of coal, the most extensive and valuable

of which is the Lower Sunday Creek field, where the coal is known as the Bayley's Run coal. This becomes the Norris coal at Millertown, and the Stallsmith seam of Hemlock and vicinity. It is also the Happy Hollow coal of Buchtel and vicinity.

The relations of these seams can be thus expressed:

	Ft.
Upper Freeport coal.	
Interval	5 to 25
Upper Freeport limestone.	
Interval	20 " 40
Lower Freeport coal.	
Interval	5
(Lower Freeport limestone), not persistent.	
Interval	25 " 50
Middle Kittanning coal.	
Interval	20 " 30
Lower Kittanning coal.	

I am nów disposed to count the Snow Fork and Norris limestones of my report on the Hanging Rock District, vol. III, as one and the same, viz., the Lower Freeport limestone. For the duplication of these and the associated elements, probably the report above referred to is responsible in larger degree than any other publication.

The subject must not be left without the further acknowledgment that there is a complexity of composition in the Upper Freeport horizon which does not appear in the sections thus far given. There is sometimes a real duplication of coals here that will appear in subsequent discussions.

The Cambridge and Ames limestones, and also the Brush Creek coal (No. 7*a*) are all steady elements in this field. The Brush Creek limestone has a large development as an impure ore (bastard limestone) in the Sunday Creek Valley. It is known as the Dugway ore near Ewing site.

Another fine development of the Upper Freeport coal is found near Nelsonville, in what is known as Happy Hollow. The Nelsonville Coal and Coke Company have opened large mines in the seam at this point, and it has proved to be a basis for successful mining. The section as seen in this vicinity is as follows, the leading elements and their intervals only being noted :

	Ft.	In.
Ames or Crinoidal Limestone	5	
Interval (85′ to 125′)	120	
Cambridge Limestone	3	
Interval (40′ to 55′)	45	
Brush Creek Coal—No. 7*a*	2	6
Interval (35′ to 45′)	40	
Upper Freeport coal—Happy Hollow Seam—(0′ to 6′)	6	
Fire-clay and Shale	12	
Buchtel Ore and impure Limestone	5	
Shales	15	
Upper Freeport Limestone—Shawnee Limestone	3	
Interval	18	
Lower Freeport coal (25′ to 55′)	2	
Lower Freeport Limestone	1	
Interval	34	
Middle Kittanning coal (No. 6)	8	

The Buchtel ore and the impure limestone associated with it are somewhat abnormal. They occur just where in most parts of the field the Upper Freeport limestone is due, but the Shawnee limestone, a few feet below, adequately represents that stratum, though separated quite widely from the coal.

We have now followed the series with which we set out as far as the Hocking Valley. It has been shown to be continuous as far as its main elements are concerned. In particular, the coal seams keep their horizons through almost all of the field, and so also do the limestones, in the main. The Putnam Hill limestone in its full development is limited to that portion of the field included between the eastern line of Perry county and the western line of Mahoning county, but it can be clearly and unequivocally traced on either side of these boundaries. But the Ferriferous limestone has now resumed its place in our sections, and though a little weak in northern Hocking and Perry counties, it becomes steady from Washington township of the latter county southward, scarcely missing a section in which it is due from this point to the Ohio river.

This portion of the field was treated of at length in my report on the Hanging Rock district (Geol. of Ohio, vol. III). The unification of the series as there established, has been fully maintained, and the sections given in that report can, without extended description or comment, be incorporated with the review already accomplished in these pages, thus continuing the series to the Ohio river.

Reference will here be made to a few disputed points in this part of the field, and to the correction of such errors as have been noted.

The account given in the report referred to, of the westward extension of the Middle Kittanning coal seam (No. 6) from Nelsonville, has been called in question by Dr. T. S. Hunt, in his reports upon the Hocking Valley coal field, and also by others. The question is of fundamental importance in its relations to the order of our coal measures, for all of the identifications of the various elements of the Southern Ohio sections are connected with or dependent upon this.

Andrews asserted in the report of 1870 the probable identity of the Carbondale and Mineral City coals with the Nelsonville seam (pp. 89–92). My report in vol. III (Hanging Rock district) confirmed his conclusion, but established this identity on other and distinct grounds.

The Carbondale coal is easily traced down Hewitt's Fork of Raccoon Creek to Mineral City, the seam being opened on every quarter section of the interval. The Mineral City coal is as easily followed by continuous workings to Hope Station and Zaleski. The character of the coal as well as its relations demonstrates the identity here claimed, an identity undisputed and unquestioned so far as is known.

At Hope Station the Carbondale coal comes into a section of which the Lower Mercer Limestone is the base and the Cambridge limestone is the summit, and that also holds the Ferriferous limestone with its ore in good development at the proper level. More could not be asked in a geological section of the Lower Coal Measures of Ohio, and conclusions built upon a consistent interpretation of such a section cannot easily be set aside.

The Carbondale coal proves to be the second seam above the Ferriferous limestone. But the identity of the Baird ore and the Ferriferous limestone ore has been already proved, and the Nelsonville seam is the second above the Baird ore. The two seams, therefore, hold the same position, and the Carbondale coal, like the Nelsonville seam, is the Middle Kittanning coal. This conclusion is supported by every line of facts that bears upon the question.

The section obtained in the vicinity of Hope Furnace is so interesting and complete, that its main facts and measurements are given below:

	Ft.	In.
Cambridge limestone at top of Rich Hollow Hill	5	
Interval	132	
Upper Freeport limestone—Shawnee limestone	—	
Interval	76	
Middle Kittanning Coal—Mineral City and Carbondale seam	3	6
Interval	27	
Lower Kittanning Coal, (No. 5)	1	
Kittanning clay	10	
Ferriferous limestone and ore, both formerly worked	2	6
Interval	14	
Kidney Ore, formerly worked	1	
Interval	34	
Coal—Tionesta (?) No. 3*b*, overlain by black slate	2	
Interval	16	
Coal—Upper Mercer, No. 3*a*	1	6
Interval	21	
Lower Mercer limestone	5	
Lower Mercer Coal and slate, No. 3	7	

There is not a clearer section in the Ohio Coal Measures than this. It has the four limestones that are most serviceable in carrying horizons from point to point. The Lower Mercer limestone in particular is in its best and most characteristic development. It lies in the bank of Raccoon Creek, and covers quite a heavy deposit of interstratified coal and slate, which is of little or no value. The limestone soon rises from the banks of the stream to the westward, and is found everywhere at its proper level. If there is any one formation that every one knows, and about which no controversy is possible, it is the Lower Mercer or Blue limestone. Various attempts have been made to mine the coal below it to the westward, but aside from small county banks, it supplies no proper basis for mining.

The Ferriferous or Gray limestone is here seen at its extreme eastern development. Everywhere to the west and south it is in full force, and its ore has been thus far the chief mineral element of value throughout this region. It was first recognized, though somewhat doubtfully, by Andrews in his report of 1870, but the section in which it occurs is in all respects normal, as I have shown in vol. III, p. 922.

The Cambridge limestone, in like manner, is unmistakable. There is no stratum with which it is in danger of being confounded. In the present section it is 212 feet above the Carbondale coal, and this measurement certainly forbids the reference of this seam to any higher horizon than

the Nelsonville coal. The interval between the Nelsonville coal and the Cambridge limestone in the Hocking Valley is generally about 180 feet, but all intervals expand to the southward, and the measure above given is quite in keeping with the general facts, on the theory that the Carbondale and Nelsonville coals are the same.

The facts of the dip are in accord with the view that the Carbondale seam is the Middle Kittanning. At Carbondale the coal is 193 feet at one entry and 200 feet at another above Lake Erie. The coal at Mineral city has fallen to 138 feet above the same base. In passing westward the strata rise slowly, the coal being 202 feet at Moonville and 248 feet at Hope Station. The Nelsonville seam would agree well with all these elevations.

By those who refuse to accept the Carbondale as the the continuation of the Nelsonville seam, the former is generally counted as No. 6*a* of the Hocking Valley series, a seam that is found 30 to 40 feet higher than the Nelsonville coal. It is the Lower Freeport coal of the general scale. This seam begins to be workable in this district about New Lexington, where it is known as the Black coal. At Moxahala it is the Fowler coal. In the vicinity of Buchtel it is often found 3 feet thick and of fair quality. It is here about as far above the Nelsonville coal as the Lower Kittanning coal is below that seam, and like the latter it is so overshadowed by the great seam that little account is taken of it.

In passing from Floodwood to Carbondale, after crossing the divide between Floodwood Creek and Hewitt's branch of Raccoon Creek, this seam is found opened in a number of country coal banks. The first of them is in Fraction XIX, York township, on the farm of Thomas Juniper. The coal seam is here 2 ft. 8 in. thick, and consists of *two* benches, the lower one being 12 inches thick and the upper 16 inches. The parting is shale and 2 inches thick. The roof is dark but not black shale. About the place and name of this coal, there is no dispute. A shaft was sunk $\frac{3}{4}$ of a mile from this point by George W. Gill, of Columbus, to the main coal, which is said to have been found 26 feet below the Juniper coal, and 6 ft. 11 in. thick.

The Juniper coal can be traced down the valley of Hewitt's Fork, as all agree. It has been opened on every farm. The last entry upon this seam on this side of Carbondale is in section 30, Waterloo township, on the land of Henry Frank, where it is again found with a single shale parting in the middle of the seam. The two benches are here

each 17 inches thick. The seam shows the same structure at all of the intermediate points, so far as could be learned. At both of these entries, and all along the line, there is a heavy and characteristic development of the Upper Freeport limestone from 15 to 20 feet above the Lower Freeport coal. This relation between coal and limestone has been maintained for the last 25 miles at least, as will be seen by the sections that have been already given. A heavy sandstone overlies the limestone, a phase of the Upper Freeport sandstone of the general scale.

The valley which we have been following from Juniper's to the Frank coal bank holds a direction a little east of south, so that its fall coincides with the dip of the coal, but below Frank's, the stream turns abruptly to the west, and thus runs *against* the dip of the coal. It is here that the mistake has been made which has led to the positive identification of the Carbondale and the Juniper coals. No one questions that the latter is the seam known as No. 6*a* to the northward. At the Frank mine, the coal has the same level that the Carbondale coal has, ¾ of a mile to the westward, but the dip brings down the upper seam in this interval to this level. It must be granted that the required dip is in excess of that usually prevailing, but it is not by any means without precedent.

At Carbondale the Upper Freeport limestone is found at 53 ft. and at 60 ft. above the Carbondale coal, but at Frank's and Juniper's, the same limestone comes in at 17 ft. above the coal. A heavy sandstone, the Lower Freeport, covers the Carbondale coal throughout this region. The Freeport limestone lies only a few feet above it in many places, in which cases the Lower Freeport coal is wanting. It is the resemblance of this sandstone to the stratum above the limestone which has helped to mislead many as to the true order. The two sandstones often appear as one undivided stratum, and yet care enough in examination will generally show the place of limestone or coal between the two elements that constitute the apparently massive rock. Andrews gives in his supplemental report an instructive example of the blending of these same sandstones in another portion of the field (vol. III, p. 853), and every geologist who has worked upon coal measure formations has met with similar cases.

A better guide is found in the Cambridge limestone. There is an outcrop of this limestone above the Frank coal, or rather above the

opening of the same seam on the opposite side of the creek on the Nanny farm. The Cambridge limestone is here 146 feet above the coal, while at Juniper's the limestone is 160 feet above the coal. These are both proper intervals for this region, but in section 29 (northwest quarter), Waterloo township, one mile south of this point, another fine exposure of the Cambridge limestone is found directly above a mine of the Carbondale coal. The interval is 210 feet, the same interval as at Brewer's cut. These measurements settle the question conclusively. The Carbondale and the Juniper coals cannot be the same seams.

The section at the last-named point is a valuable one. It shows the Mahoning sandstone in great force, and also the Lower Freeport sandstone in strong development. It is as follows:

	Feet.
Cambridge limestone	2
Interval concealed	58
Mahoning sandstone, massive	54
Interval concealed	55
Lower Freeport sandstone, massive	35
Shales	6
Carbondale coal	4

The Upper Freeport coal is found at Carbondale 80 to 90 feet above the Carbondale seam.

The structure of the Carbondale coal is equally conclusive. It is a 3-*bench coal* throughout all of the extensive workings at Carbondale, and throughout all the district with which it is directly connected. The structure is uniform and regular to a high degree. It is as follows:

	Inches.
"Nigger-head"—Black shale, with fossil wood	12
Coal—inferior quality	12
Clay parting	4
Coal	28
Slate parting	1
Coal	8
	53

This is the Nelsonville coal with the upper and lower benches reduced. The most characteristic feature of that seam is the 28-inch second bench. The Carbondale coal cannot become in half a mile the two-bench coal of Frank's and Juniper's banks without a great anomaly. The Lower

Freeport coal is often a 3-bench coal, it is true, but it is not in this neighborhood, as has been already shown.

If the Carbondale coal were the Lower Freeport seam, then the Nelsonville seam should be shown, as the strata rise to day along the valley of Raccoon Creek. There are chances without end to see every foot of the strata for 150 feet below the Carbondale coal along the line of the Marietta and Cincinnati Railroad, westward from Mineral City. The road is a long established one, and it has not spared pains to develop the coal seams along its line. Every seam that has held out any promise has been opened and proved within the last 25 years, but the result is that the Carbondale seam is the only one that is worked. It is not possible that a thicker and better seam lies undeveloped in this district where everything is naked and open.

Again, if the Nelsonville seam were below the Carbondale coal, it should be found in borings at that point. Such borings have been made, and the records are known.

Alexander Todd, Esq., of Loveland, Ohio, was Manager, and afterwards President of the Southern Ohio Coal Company during the years 1869–70. Under his supervision, a hole was bored, starting from the level of the Carbondale coal within 20 feet of the mouth of the main entry. The earth was removed until the bedded rock was reached, and then the drill was started. The hole was carried down $87\frac{1}{2}$ feet. A thin sandrock was first passed. At about 30 feet, an 18-inch seam of coal was passed (Lower Kittanning), but nothing else in the way of coal was found.

Many other borings have been made in the valley, and if any one had ever struck a 6-feet seam of coal, shafts would have gone down within a year. All of the claims that are made as to the proved occurrence of a thick coal below the surface in this immediate region are without good foundation.

The identifications of the Nelsonville coal in the valley of Raccoon Creek, as made by Hunt in his "Mineral Resources of the Hocking Valley" (pp. 9, 25 and 27), are entirely inadmissible. In all instances but one, the seam, as thus followed, is found in reports of borings and shafts, but these reports neither agree with each other nor with the facts. The only instance where he finds the Nelsonville coal, according to his view, coming to day, is in the bed of Raccoon Creek in section 19, Brown township, near Brewer's cut on the M. & C. R. R. The 7 feet

of coal and slate that are here found are counted by him as the true Nelsonville coal. But these 7 feet of coal and slate are capped with 5 feet of as characteristic Lower Mercer limestone as there is in Ohio. This coal seam has an elevation above Lake Erie of 103 feet. The Ferriferous limestone with its ore, a worked horizon, is found 102 feet above it; the Carbondale coal, 136 feet above it; and the Cambridge limestone, 348 feet above it, all in the same section. There is not a clearer or less ambiguous section in the Lower Coal Measures of Ohio.

The combined section at Carbondale is shown in Fig. XXII, in which most of the elements and measurements already given are incorporated. By the side of it is shown the Brewer's cut section, Brown township, to which reference has just been made, and which was also given on a previous page. The combined section A has the fault of its kind, that it gives in a single column elements that are not found in any one vertical series, and some minor deviations will therefore be found from the measurements obtained in the separate sections, but no difficulty will be experienced in understanding the facts as thus represented.

The accompanying sketch map, Fig. XXIII, shows the locations of most of the points involved in the immediate vicinity of Carbondale. The differences in elevation were determined by the engineer's level.

The name and place of the Carbondale coal have been treated thus at length because a wrong determination would vitiate all of the connections of the Hocking Valley coal field with the Hanging Rock District. The reference of it, first made by Andrews, to the Nelsonville coal proves to be the correct reference, and the question may now be counted among the settled ones in Ohio geology.

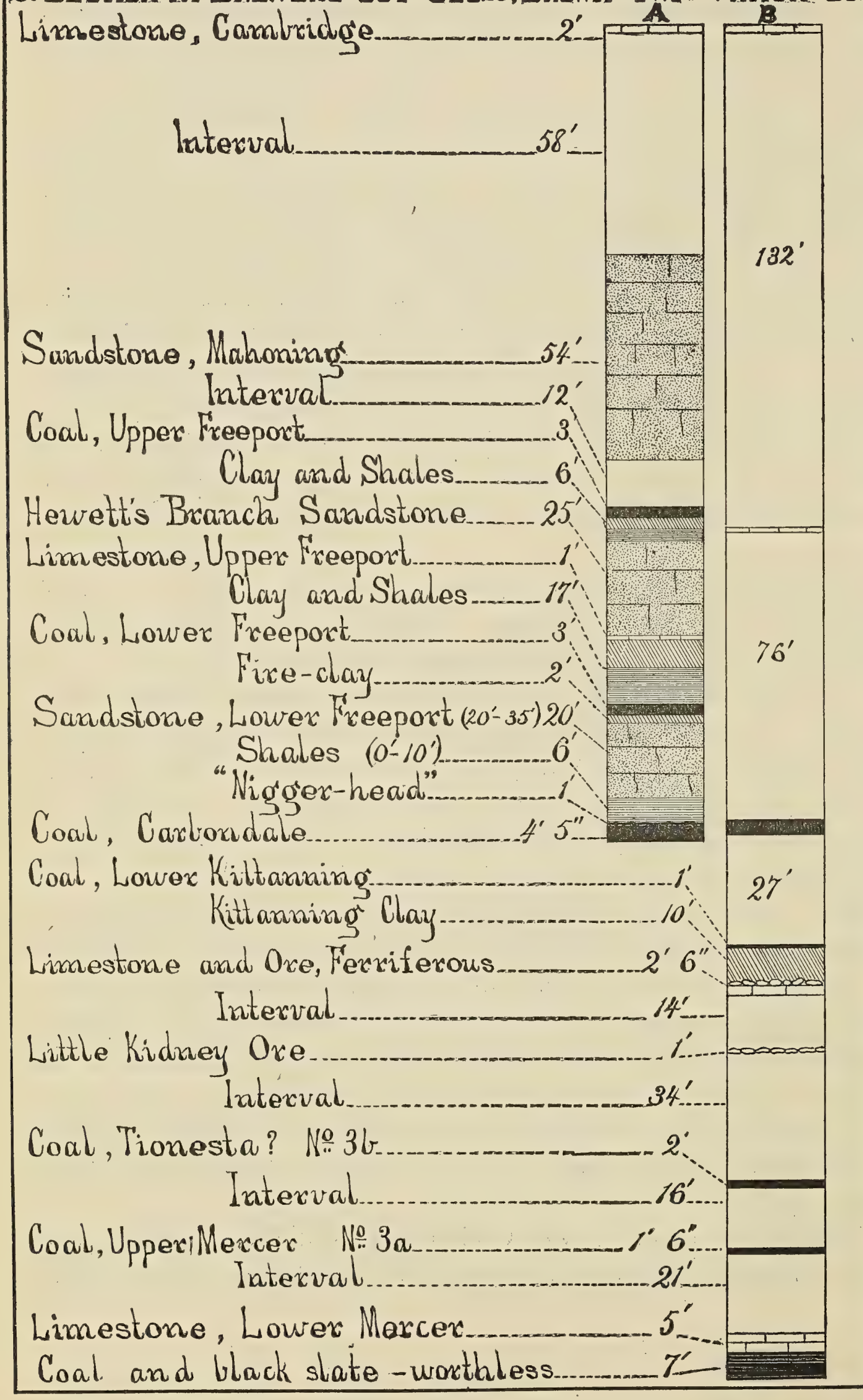
The sections which we have last considered have carried us into a new field, viz., the Hanging Rock District of Southern Ohio. We have now reached the most northerly of the great furnace tracts that are located upon the outcrop of the Ferriferous limestone. To continue the examination of the series in the same detail with which we have thus far advanced, is no longer necessary, for from this point to the Ohio River there is one dominant horizon, which is everywhere worked, and which every one knows, and about which dispute is out of the question.

If the unity of the Lower Coal Measures of Ohio, and the persistence of their main beds are considered established by the facts

FIGURE XXII

A. SECTION AT CARBONDALE SEC. 30, WATERLOO TWP. ATHENS CO.

B. SECTION AT BREWERS CUT SEC. 19, BROWN TWP. VINTON CO.



already presented, from the Pennsylvania border to the point which we have now reached, then this unity and persistence may be counted established for the whole margin of the coal field in the State.

The stratigraphical order of the Hanging Rock District was in the main clearly shown in my report upon that field in volume III, Geology of Ohio. The general section there published has proved a true one for almost every portion of the series, and has become an accepted guide in the practical development of the region. An error of some magnitude, and very confusing to the true order is, however, to be found in the position assigned to the Maxville limestone. This limestone is undoubtedly of Sub-carboniferous age, and is geologically below both the Wellston and the Jackson coals, whereas, the section reverses this true order. The view so strenuously maintained by Andrews in regard to this point was the true one. The number of coal seams, however, and the intervals between them were correctly given, with the exception already noted in regard to coal No. 6*a* and coal No. 6*b*. These two seams should be merged in one. There is also an extra coal seam shown about the Lower Mercer limestone that probably nowhere reaches any profitable development. When these errors are corrected, the section will serve as well as any that could be constructed now, to indicate the general order of the field.

One important error in the application of the section will presently be noticed in treating of the Waterloo coal field of Walnut township, Gallia county.

A brief resume of the essential facts will be here given, and the elements, as far as they can be certainly identified, will be named in accordance with the section that we have brought along from Pennsylvania to the borders of the Hanging Rock field.

The Ferriferous limestone is the key to the series, the common bond for the several portions of the field.

Above it are everywhere found the two Kittanning coals, as steady and regular as they are in any like area of their wide extent.

The limestone is generally covered with 5 to 15 feet of white clay, the well-known Kittanning clay of Pennsylvania and Eastern Ohio. Throughout the Hanging Rock District, this is a valuable, though for the most part an undeveloped horizon. It is generally a plastic or potters' clay, and is sometimes very pure and rich. There is sometimes

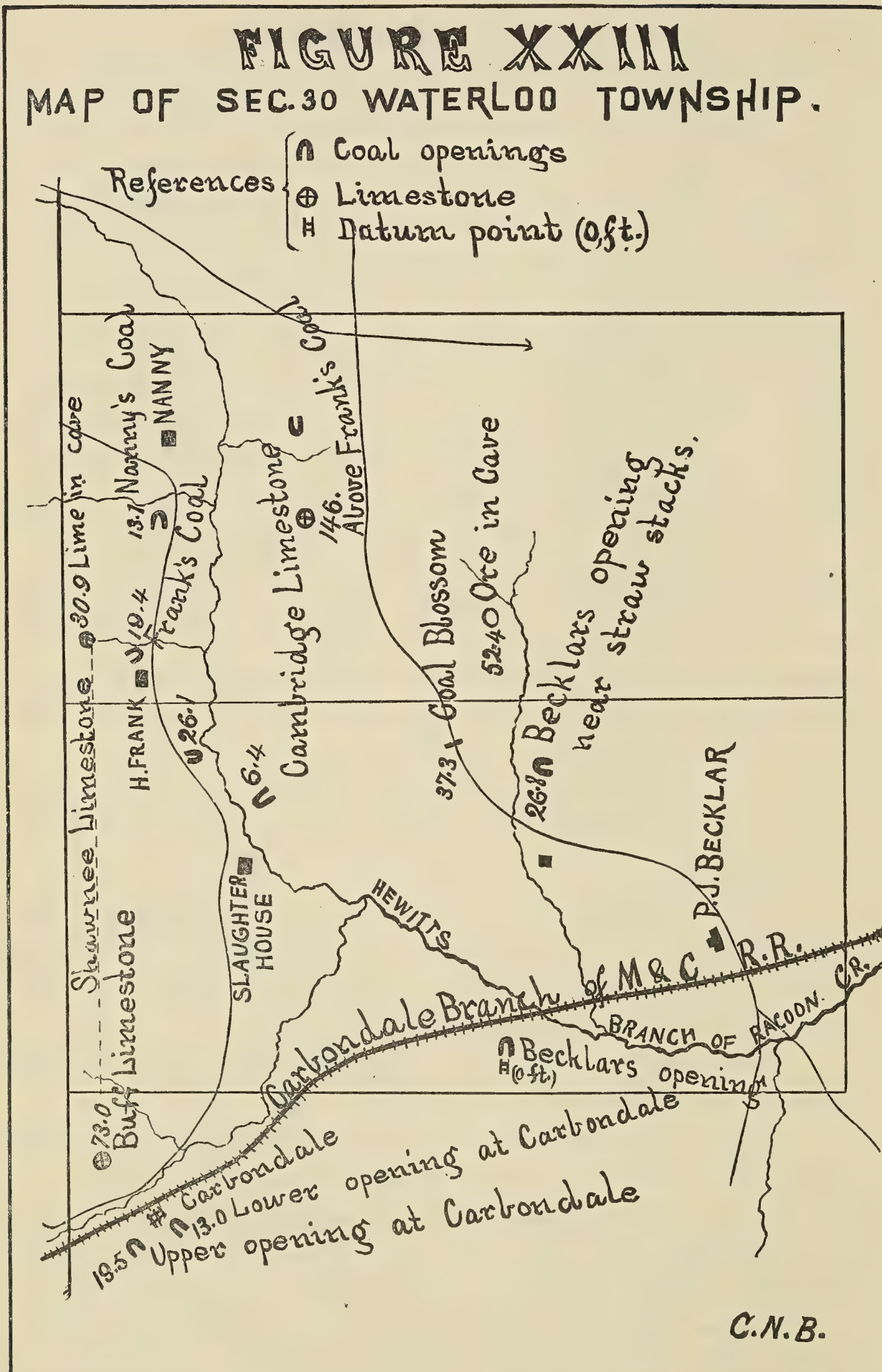


FIGURE XXIII
MAP OF SEC. 30 WATERLOO TOWNSHIP.
References
Coal openings
Limestone
Datum point (0 ft.)
Cambridge Coal
NANNY
Nanny's Coal
30.9 Lime in cave
13.1
19.4
Frank's Coal
H. FRANK
Shawnee Limestone
26.1
Cambridge Limestone
146.
Above Frank's Coal
6.4
Coal Blossom
37.3
52.40 Ore in Cave
Becklars opening near straw stacks.
26.8
P. J. BECKLAR
SLAUGHTER HOUSE
HEWITTS
Carbondale Branch of M & C R.R.
BRANCH OF RACOON CR.
Becklars opening
H (0 ft.)
73.0 Buff Limestone
Carbondale
13.0 Lower opening at Carbondale
19.5 Upper opening at Carbondale
C.N.B.

found above the coal a hard or non-plastic clay, as at Portland, Jackson county, which is of excellent quality.

The Lower Kittanning coal is separated from the limestone by an interval varying between 9 and 30 feet. In the northern portion of the field, the smaller measure prevails. In Lawrence county, the usual measure is 25 to 30 feet, a heavy sandstone sometimes setting in. The coal is workable at many points, but it attains the greatest value in the southern part of Lawrence county, about New Castle. It is best known as the New Castle coal, on this account.

The second coal above the limestone or the Middle Kittanning coal has the same relative prominence and value in this field that it has in so many other districts through which we have passed in our review. We have just left it in the Hocking Valley as the Nelsonville coal, the thickest and most profitable seam in the State. We found it thinning down into the Carbondale coal, which was still further reduced in the Mineral City seam. It is in this thinner and weaker phase that it extends over the northern half of the Hanging Rock field. There are considerable tracts in Vinton and Northern Jackson counties where it does not admit of being mined with profit, though its place is always marked, but from Jackson county southward it gains somewhat in volume, and gives rise to many country mines. At Washington Furnace, it is extensively worked for iron manufacture, being used raw in the furnace with great success. The coal seam is less than 3 feet in thickness here. It is 4 feet 2 inches thick, and of excellent quality at Evans's Mills in Greenfield township, Gallia county. On the Ohio River at Sheridan, it has been worked on the large scale, and it attains still greater value south of the Ohio River in the Coalton District of Kentucky.

A heavy sandstone underlies it at some little distance, the Kittanning sandstone of our general scale, and a heavy sandstone *over*lies it everywhere, the Lower Freeport sandstone.

The Lower Freeport coal has a good deal of value throughout the field. It is the Hamden Furnace coal of my report in volume III, and also the Hatcher coal of the same report. It is frequently a thicker, and therefore more valuable seam than the Middle Kittanning below it. The interval between these seams ranges from 30 to 55 feet. In the northern portion it holds the former measure, but in volume III it was shown that this interval slowly expanded until it became about 50 feet for the general measurement.

The Lower Freeport limestone is quite a steady element of the scale in the southern portion of the field. Its place is generally 8 to 10 feet below the coal. It is known as the Lower Buff limestone, and is the Snow Fork and Norris limestones of the report in volume III.

The fourth coal above the Ferriferous limestone is the Upper Freeport seam. Both coal and limestone are well developed throughout the district, the limestone as usual being much steadier than the coal. The interval between coal and limestone is reduced to a few feet once more, as in the central and eastern portions of the State, and unlike the condition in the Hocking Valley.

The coal displays its usual capricious and changeable character. It is workable at a large number of localities, but it does not maintain itself from point to point.

There is in the district one field of unusual promise, comparable to the Dell Roy or the Cambridge field, though probably less extended than either of these. It is known as the Waterloo coal field. A serious error exists in my report in volume III, with reference to the Waterloo coal. It was identified as the Nelsonville or Sheridan seam. This was an error of precisely the same character as that which was made in regard to the Dell Roy coal, when it was pronounced No. 6, or the Middle Kittanning coal. In both cases the location of the seam, so far from the margin of the field, furnished an antecedent probability that the seam must belong to a higher horizon than the Middle Kittanning coal. In the case of the Waterloo coal, there was no error of the general section involved, but only an erroneous application of the section. For the correction of this error, we are indebted to Mr. Emerson McMillin, of Ironton.

At Olive Furnace, the seam becomes once more for a limited extent a blackband horizon. The limestone of the series becomes in many cases an ore, sometimes of excellent quality, but generally so uncertain in regard to its percentage of iron as to be unfitted for furnace use.

The Brush Creek coal (Salineville Strip Vein) is a regular member of the series. It is No. 7*a* of the report in volume III. A coaly streak occurs quite constantly in the interval between this and the Upper Freeport coal, but it does not deserve a place in the list of coals. The Brush Creek coal seldom reaches 30 inches in thickness, but its quality is generally excellent. There are but few mines opened in it, but its place is always recognizable. The Brush Creek limestone (third buff lime-

stone) is quite a constant element. The coal is overlain by the second stratum of the great Mahoning sandstone, a much heavier and coarser ledge than the lower division which overlies the Upper Freeport coal. The upper sandstone is the Buffalo sandstone of White's Report on Lawrence County, Pennsylvania. The thickness of the Mahoning sandstone (lower) may be taken as 25 feet, and of the Buffalo sandstone or Upper, as 40 to 50 feet.

The ores that help to mark the series and establish connections have been mainly omitted from this review, but they are better known in the furnace tracts than the coal seams, though less widely distributed through the field at large.

The intervals between the leading elements of the scale are as follows:

	Feet.
Cambridge limestone, in two strata, 10 to 20 feet apart.	
Interval (from Upper Cambridge)	55 to 70
Brush Creek coal—No. 7*a*.	
Brush Creek limestone—Upper Buff limestone.	
Interval (from B. C. coal)	40 to 60
Upper Freeport coal—No. 7, Waterloo seam.	
Upper Freeport limestone.	
Interval (from U. F. coal)	30 to 50
Lower Freeport coal—No. 6*a*, Hatcher seam.	
Lower Freeport limestone.	
Interval (from L. F. coal)	30 to 55
Middle Kittanning coal—No. 6, Sheridan seam.	
Interval	25 to 45
Lower Kittanning coal—No. 5, New Castle seam.	
Interval	20 to 35
Ferriferous limestone and ore.	

For the representation of the series from the Ferriferous limestone to the Cambridge limestone, inclusive of both, the general section prepared by E. McMillin, of Ironton, for the Ironton and Northeastern Railway Company, is hereby reproduced with the permission of the author. The names of the coal seams, as now understood, are inclosed in brackets, the only addition to the section.

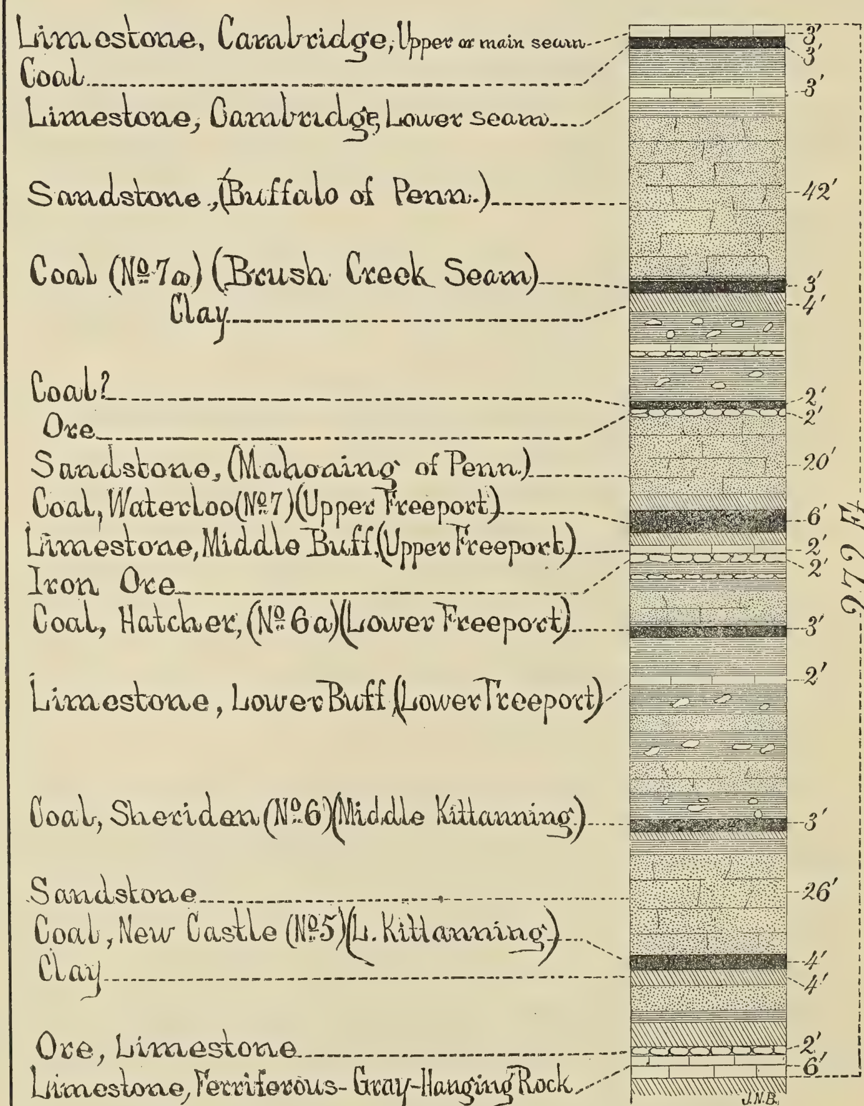
This section illustrates the wonderfully close agreement of this portion of the scale with the several fields that have already been passed in review.

The series below the Ferriferous limestone is by no means as clear or as well understood as the series above, but there are many well-settled

FIGURE XXIV

GENERAL SECTION, LAWRENCE CO.

E. McMILLIN



facts, to a few of which attention will now be called. The Lower Mercer limestone will be counted the lower limit of the series in this review.

Immediately below the limestone, there is found throughout much of Vinton and Jackson counties a valuable coal seam from 3 to 5 feet thick, and a main source of fuel for the territory in which it occurs. It is everywhere known as the Limestone coal. It fails to accompany its limestone to the southward, being seldom seen in Lawrence county, neither does it extend to the northern limits of the limestone, but in the region of its development it is as steady as the limestone itself. It is evidently the Scrub Grass or Upper Clarion seam of our general section. It sometimes drops away from the limestone as much as 12 or 15 feet.

The Putnam Hill limestone with its coal (No. 4 of Newberry) can be followed *into* the field with certainty, but it can be followed *through* the field with only a high degree of probability.

We find it in good development as a limestone and flint horizon in northern Vinton county at a distance of 30 to 50 feet below the Ferriferous limestone.

On the Dunkel farm near Creola, Swan township, it is found 35 feet below the Ferriferous limestone and ore. The Putnam Hill limestone is here shaly and very fossiliferous, and enclosed in white clay. On the Feeogh farm, east of railroad from Swaim's Station, it is found as a 4-feet flint, underlain with a thin coal, and with a 10-inch streak of coal directly above it. It is about 50 feet below the Ferriferous here. At McArthur, the flint shows in force on the Felton farm, a mile south of town. Through all of this neighborhood the coal seam of this horizon is mineable and valuable. It is a two-bench coal, 4 feet thick, and it yields a light white ash. It is locally known as the Winters coal, and also as the Flint Vein.

The horizon is further conspicuous from the valuable iron ore that is associated with it, the seam lying directly beneath the fire-clay of the coal. This ore is known as the limestone kidney. It is largely worked and highly esteemed. A smaller kidney ore occurs 20 or 30 feet above it.

By means of the kidney ore we can trace the horizon well down into Jackson county, but the ore fails before the southern line of the county is reached. It seems very probable that the Conway coal of

Lawrence county is to be referred to this horizon. Its place is about 50 feet below the Ferriferous limestone, and it is frequently mineable, its thickness never exceeding 3 feet, however, so far as known.

The probable representative of the Brookville coal is thus seen to have a place on the western shore of the coal field.

The Tionesta coal of Pennsylvania seems to be represented in the Newland coal of McArthur. This seam in its largest phase is made up of two distinct beds, which are separated by 12 to 15 inches of shale. The upper portion is often cannel. Further south, two or three coal streaks scattered through 15 to 20 feet of shales, hold the same horizon. This is No. 3*b* of my report in volume III. It can be easily identified by its relation to the main or upper block ore of the Ohio valley. It lies a few feet above this widely-known horizon.

The Upper Mercer horizon is remarkably distinct throughout the entire field, but its chief value lies in the ore which it bears. The limestone itself, or the flint that replaces it, is found at intervals all along the line, but the ore continues where the limestone fails. The ore is the now famous Dunkel block ore, or Swan township ore, or Creola block ore of Vinton county, the Big Red Block of Jackson county, and the Main block ore or Franklin Furnace block ore of Lawrence and Scioto counties.

The coal of this horizon is generally thin, and no considerable mines are known in it.

The interval that separates the Upper and Lower Mercer limestones varies in different portions of the field. It is 30 to 40 feet in Vinton county. It becomes 50 feet or even 60 feet in the lower counties.

The Lower Mercer limestone and its coal and ore are so well determined that they require no detailed description here. This horizon, next to the Ferriferous limestone, is the easiest to follow, and the hardest to lose in the Lower Coal Measures.

The series that have been thus far described can be more clearly shown by arranging the elements in vertical order, and indicating the interval that separate them.

Ferriferous limestone.	
Coal—Upper Clarion or Scrub Grass, limestone vein.	
	Feet.
Interval, frequently embracing the Hecla sandstone (from limestone)	30 to 60

	Feet.
Putnam Hill limestone.	
Coal—Brookville? Winters coal, Conway coal? No. 4 of Newberry.	
Ore—Limestone kidney.	
Interval	20 to 30
Coal—Tionesta? Newland coal, No 36.	
Interval	10 to 20
Ore—Dunkel Block, Franklin Block, Main Block.	
Upper Mercer limestone or flint.	
Coal—Upper Mercer.	
Interval	30 to 60
Ore—Lower Mercer, Blue limestone block, Little block.	
Lower Mercer limestone.	
Coal—Lower Mercer.	

The whole interval between the Lower Mercer and Ferriferous limestones ranges between 90 and 160 feet. It is quite steady at the latter figure in Lawrence county. In northern Vinton it is about 100 feet, but in the central parts of the county it becomes 130 to 140 feet.

The object for which this chapter was undertaken has now been accomplished. The series with which we set out at Lowellville, on the Pennsylvania, line has been traced around the entire Ohio border of the Lower Coal Measures. It has been made plain that a large number of these horizons, and that some of the individual elements, are continuous throughout the whole extent of country that has been traversed. The Freeport Group, the Kittanning Group, and the Mercer Group can be named as signal examples of this persistency. To a considerable extent, lithological and chemical characteristics are maintained in the several members of these horizons throughout their entire extent. The statements which would properly describe the Lower Mercer limestone in Mahoning county would describe it in Jackson or Scioto counties without the change of a word. The same thing is true of the Freeport limestones.

The Kittanning clay retains the same characteristics in Lawrence county, Ohio, that it has in Lawrence county, Pennsylvania. The Limestone ore of the Hanging Rock field has the same peculiarly excellent quality that characterizes the Buhrstone ore of Western Pennsylvania.

The Kittanning coals are noted for their steadiness throughout all of the territory that they occupy, while the Freeport coals are everywhere sporadic and uncertain.

Different conditions of growth and accumulation are indicated by such facts, and glimpses are afforded in them of the physical geography of these distant periods.

The connections, which it has been the object of this chapter to establish, have been made to rest as little as possible upon assertion. The ability to recognize the several Coal Measure limestones, the Mercers, the Putnam Hill, the Ferriferous, the Freeports, the Cambridge, and the Ames, is of course involved in the construction of sections in which these elements occur, but they are so well characterized as a rule that it is not asking very much that this ability shall be conceded. The identifications made by others, and continuity that is based on general knowledge, have been brought into requisition in very many instances. Even the measurements of other geologists have been frequently adopted in order that the conclusions may be seen to rest as far as possible on the consenting and harmonious testimony of many, rather than on the judgment of one.

The illustrative sections might have been multiplied indefinitely, but it is believed that enough have been given to weld the series of the several fields. It is not denied that in the establishment of this unity of history, such sections as would best illustrate it have been selected, but in all cases the range of measurement and variation has been stated for the several subdivisions of the field.

The uncertainty in which some questions of identification have been left is not the result of unusual obscurity in the subjects themselves, but rather of the necessary haste with which the work of exploration has been conducted. There are but few insoluble problems, to say the least, of a stratigraphical character in the Lower Coal Measures of Ohio.

The results of the investigations that have here been recorded may be thus expressed. There are in the Lower Coal Measures of Ohio, or in other words, below the lowermost division of the Mahoning sandstone, twelve regular seams of coal, all of which are of mineable thickness (24 inches and over) in some part of their extent. In this enumeration, the Lower Clarion and Upper Clarion (Scrub Grass) are counted as distinct seams. Furthermore, there are two seams that are found in a great many sections, the No. 5*a* of Newberry from the Tunnel section at Mineral Point, and the 18-inch seam so often found between he Middle Kittanning and the Lower Freeport coals in Columbiana

and Jefferson counties, that might be added to the number, but as they are nowhere known to be workable, they are omitted.

The names of these coals in the Pennsylvania system are as follows, some of their Ohio synonyms being placed in parallel columns:

Coal Seams of the Lower Coal Measures of Ohio.

12. Upper Freeport coal.......	Coal No. 6 and Coal No. 7..........	Big Vein of Salineville, Dell Roy seam, Cambridge, Alexander, Bayley's Run, Norris, Happy Hollow, Waterloo.
11. Lower Freeport coal. (Upper Kittanning coal).	Coal No. 5 and Coal No. 6*a*.	Roger, Steubenville shaft, Hamden Furnace, Hatcher.
10. Middle Kittanning coal (No. 5*a* coal).............	Coal No. 6 and Coal No. 4..........	Strip Vein of Hammondsville, Osnaburg, Pike Run, Dennison, Coshocton, Zanesville, Straitsville, Nelsonville, Carbondale, Sheridan.
9. Lower Kittanning coal....	Coal No. 5, Coal No. 4, and Coal No. 3.	Leetonia, Mineral P'nt, New Castle, Lower New Lexington, Creek Vein, Hammondsville.
8. Upper Clarion coal.........	Scrub Grass, Coal No. 4*b*............ Coal No. 4, and Coal No. 3.	Canfield cannel, Creek Vein, New Lisbon, Limestone coal of Vinton county, etc.
7. Lower Clarion coal.........	Coal No. 4*a*.	
6. Brookville coal...............	Coal No. 4.	Gray limestone coal of Stark Co., Evansdale, Greentown, etc.
5. Tionesta coal	Coal No. 3*b*.	Bolivar, McArthur, (Newland's), Vinton Furnace (?)
4. Upper Mercer coal.........	Coal No. 3*a*.	Bryce Coal of Canfield, Bedford cannel, Coshocton county.
3. Lower Mercer coal.........	Coal No. 3.	Blue limestone coal, Wick & McDowell's coal of Canfield, Flint Ridge cannel.
2. Quakertown coal............	Coal No. 2.	Wellston (?)
1. Sharon coal.....................	Coal No. 1.	Block coal, Brier Hill, Youngstown, Massillon, Jackson shaft (?)

A section embracing not only the coal seams, but all the main elements of the Lower Coal Measures of the State, is given below:

MAHONING SANDSTONE—CONGLOMERATIC, MASSIVE.

Upper Freeport coal and blackband ore of Tuscarawas, etc.
" clay or Bolivar clay.
" limestone.
" shale or sandstone.
Lower Freeport coal.
" limestone.
" sandstone, conglomeratic; sometimes shale.
Middle Kittanning coal.
Shale and kidney ore.
Kittanning sandstone.
Lower Kittanning coal.
Kittanning clay—Mineral Point.
(Shale and sandstone).
Ferriferous limestone and ore.
Clarion coal, Upper or Scrub Grass.
Sandstone—Hecla.
Putnam Hill limestone.
Brookville coal.
Sandstone or shale—Tionesta.
Tionesta coal.
Upper Mercer limestone or flint, with ore.
Upper Mercer coal.
Shale.
Lower Mercer limestone and ore.
Lower Mercer coal.
Sandstone—Massillon; upper division.
Quakertown coal.
Sandstone—Massillon, conglomeratic.
Sharon or Brier Hill Coal, with Mahoning blackband.
Sharon Conglomerate.

CHAPTER II.

THE COAL SEAMS OF THE LOWER COAL MEASURES OF OHIO.—IN PART.

By Edward Orton.

In Chapter I, the general order of the Lower Coal Measures of Ohio has been discussed. In treating of this subject, the various coal seams that these measures contain, have come in for a large share of attention, as the most valuable, the most characteristic and the best known members of the series, but they have been treated only as stratigraphical elements, the place of which in the general scale was to be determined, and whatever references have been made to the characters, qualities and uses of the coals, have been merely incidental and in furtherance of the main object of the chapter.

But these last-named points certainly deserve a distinct and full consideration, and the present, and one or more succeeding chapters, will accordingly be devoted to the coal seams of the Lower Measures in their economic aspects. These several seams will be treated with reference to their (1) extent, their (2) qualities and uses, and their (3) present development as bases of mining. The methods of coal mining employed in the State will be the subject of a separate chapter.

Methods of Designating Coal Seams.

Before entering upon the discussion, it will be necessary to determine the names or designations by which the coal seams shall be known in this report.

In the naming of the coals of the Appalachian field, two systems are in use. The first, which is far the most widely employed, gives a name to a coal seam from some locality where it is well developed or mined on a large scale. The Pittsburgh, Freeport, Nelsonville and Massillon coals are examples of coal seams named on this plan.

The second system designates the seams by letters or by numbers. Lesley. in his "Manual of Coal and its Topography" as well as in earlier contributions to the First Pennsylvania Survey, made use of letters, styling the Brookville coal, coal A, the Clarion coal, coal B, etc., but in the reports of the Second Pennsylvania Survey, now in progress, he emphatically discards and repudiates this method. (Q 2, Preface, p. xxix. Note.)

Newberry introduced the use of numbers for the same purpose in his reports on the Ohio coal-fields. The system first appears in the Report of Progress for 1870 (p. 26 et al.), but it was considerably modified in his more formal and extended treatment of the subject in volume II of the final reports (pp. 130–131.) The Wellston coal is here referred to. There is much to be said in favor of the use of numbers in such a classification. They certainly afford the most convenient designations. *Number* 5 is spoken and written more easily than *Lower Kittanning.*

Furthermore, the number definitely suggests the position of the seam in the series, while the local name can do so only in an indirect way. When we identify a coal seam as the Lower Kittanning, we assign to it as definite a place in the series as a number could do, but we are obliged to call to mind a greater number of facts in reaching the conclusion. Lesley's objections to letters and numbers in the passage referred to above, do not seem well taken. They are valid against a system of numbers that is applied before the facts in regard to the series are known, but they will hold with equal force against any other system of identifying and naming the beds of different localities under like condition.

It is certain, that no important and widely extended coal seam exists in Western Pennsylvania that has not been taken account of by the Survey now in progress there. Such a seam could not have been missed alike in outcrop and in boring during the protracted and thorough examinations, scientific and practical, to which the coal measures of that State have been subjected. If numbers or letters were now used to designate these coal seams, it would never be necessary to change them. Any sporadic or local deposit hereafter discovered could easily be intercalated in the numerical scale as it would need to be in the geological column.

The strongest objection that appears is, that such numbers might stand in the way of correlating the series of widely separated fields, as

the Anthracite region of Eastern Pennsylvania, for example, or the New River coal-field of West Virginia, in which, possibly, many new elements may be found.

But whatever theoretical advantages a numerical system of designating coal seams may possess, it becomes necessary to abandon the system now in force in Ohio on the following grounds:

1. It is inadequate. There are but 7 numbers used to represent the coals of the Lower Measures, and the uppermost one of these beds, as counted by Newberry, viz., the Salineville Strip Vein, is above the lowest number of the Mahoning sandstone, and therefore a Barren Measure coal, if the old boundaries of the subdivisions are respected. But as shown in Chapter I, there are certainly 11, and possibly 13 seams in the series that deserves enumeration. If the Salineville Strip Vein be added, there are 14 seams. One-half of the seams must therefore be belittled by intercalated numbers.

2. The system is inconsistent. The number 2, for example, is fixed upon a horizon in which there is not a coal mine to be found in the State, except in one district of one county, and even here the application of the number is a disputed point.

This district is an important one, it is true, but there are several widely distributed seams that are mined in a number of counties that were left without any place in the scale. The Tionesta coal is an example. It is mined in Mahoning, in Tuscarawas and in Vinton counties, but it has no number. The Upper Mercer coal is another example. It is mined in Mahoning county, and in Holmes and Coshocton counties, it furnishes the thickest and most valuable deposit of cannel coal in the State, but it rests under the cloud of an intercalated number, viz., 3*a*. A still more glaring case of this inequality is found in the treatment of the Lower Freeport coal, which is the basis of mining in one of the most important fields of the State, viz., the Steubenville field. This field must be known from Stark county westward as No 6*a*.

3. The system is confusing and misleading to a great degree. The Freeport coals, one of which has just been cited, are cases in point. They are known as Nos. 5 and 6 in Columbiana county. In Stark county they are Nos. 6*a* and 7. In Carroll county they are 5 and 6 in the central and southern parts of the county, and 6*a* and 7 in the northern townships. In Jefferson county, the Lower Freeport is called No. 6.

Number 4, as has already been shown, is applied to the Putnam

Hill limestone seam (the Brookville coal?) in Stark county. In the adjoining county of Mahoning, it designates the Clarion coal. In Columbiana county, the Lower Kittanning coal becomes No. 4, and in Jefferson county, the same number is applied to the Middle Kittanning coal.

Other numbers are of course involved with these. The chief trouble arises from the dislocation of the series under the Tuscarawas river divide, to which attention has already been called.

It is not necessary to multiply examples, for it is already obvious that the system, as it now stands, is a hindrance and not a help to the proper understanding of the series. Nor would it be enough to recast the system so as to remove the contradiction that now exists in regard to the Freeport coals. Such a scheme is possible. It would read as follows:

Salineville Strip Vein	No. 7*a*
Upper Freeport Coal	No. 7.
Lower Freeport Coal	No. 6*a* (or *b*)
(Upper Kittanning Coal)	(No. 6*a*?)
Middle Kittanning Coal	No. 6
Lower Kittanning Coal	No. 5
Upper Clarion Coal or Scrub Grass	No. 4*b*
Lower Clarion Coal	No. 4*a*
Brookville Coal	No. 4
Tionesta Coal	No. 3*b*
Upper Mercer Coal	No. 3*a*
Lower Mercer Coal	No. 3
Quakertown Coal	No. 2
Sharon Coal	No. 1

But the objections to this have already been shown. It would be full of inconsistency and relative injustice, and would keep the errors which made it necessary in conspicuous sight so long as it should be maintained. It would moreover require changes in numbers throughout our most important fields, and thus would be subject to the disadvantages of a reconstructed system without its corresponding gains.

Two courses present themselves as practicable, viz., to ignore the use of numbers, and to adopt the local names of the Pennsylvania seams so far as continuity can be proved or reasonably inferred, or to begin the numbering anew on the basis of present knowledge. The series would, according to these two views, be thus represented:

Brush Creek	13	XIII
Upper Freeport	12	XII
Lower Freeport	11	XI
Middle Kittanning	10	X
Lower Kittanning	9	IX
Upper Clarion	8	VIII
Lower Clarion	7	VII
Brookville	6	VI
Tionesta	5	V
Upper Mercer	4	IV
Lower Mercer	3	III
Quakertown	2	II
Sharon	1	I

By the use of the Roman numerals, as shown in the third column, numbers could be used, which in written form would be distinguished from the old series, but on the whole it is counted safe to adopt the Pennsylvania names, and they will accordingly be used in this report.

An argument for their use can be found in the established rules of geological nomenclature. These names are first in the field. The name of a coal seam of great economic value ought to have as firm a tenure as the name of a sandstone ledge without economic value. If the name Mahoning sandstone is retained for a well-known stratum of sandrock, the name Freeport coal, for example, can scarcely be dropped from an equally well-known coal seam. Both are continuous by the same token, for the sandstone is the roof of the coal.

But no system can be adopted that will enable us to dispense with synonyms. For a long while to come, whoever writes on the coal seams of Ohio will be doomed to a wearisome repetition of synonyms, if he guards himself against being misunderstood. Many years must elapse before our geology can be freed from the confusion that has come into it through the premature application of numbers as the designations of coal seams.

This system of notation proved acceptable to the people at large, as is attested by its rapid spread through all of our coal fields. Its scant list of numbers made it possible to apply them all in almost every district, so that the incongruities and contradictions of our geological literature are more than paralleled in the popular applications of the system.

A system of designating the coal seams having been adopted, a brief and general description of the Ohio coal field will be given, and

the several coal seams already named will also be characterized in general terms before the detailed examination of the various coal-producing districts of the State is entered upon.

The Ohio Coal Field.

The Ohio coal field is the northwestern prolongation of the Appalachian coal field, which, with its outliers, constitutes by far the most important source of coal for the North American Continent. The area of the entire field is estimated approximately at 60,000 square miles. (59,105 square miles, C. H. Hitchcock, Ninth Census, U. S.) One-sixth of this area is estimated to belong to Ohio. (10,000 square miles, Newberry.)

The whole field is one of remarkable symmetry and regularity, and of its several subdivisions, the portion belonging to Ohio and Northwestern Pennsylvania is the most symmetrical and regular. There is nowhere known a more orderly series of coal measure deposits than those included in this territory.

It is traversed by a few gentle folds, but these serve to aid rather than to confuse the reading of the system. There is not throughout the Ohio field a fault worthy of the name, and there is no unconformability, except the slight amount due to overlap in the lowest portion of the series. The dip of the strata is so slight that it can be determined only by triangulation. The clinometer is a superfluous instrument in Ohio.

The physical side of the history of the growth of the Coal Measures of Ohio is strictly in keeping with the same phase of the history of the underlying formations for several previous geological periods.

At the beginning of Lower Silurian time, all of Ohio lay beneath that arm of the sea which was enclosed between the Appalachian border and the Canadian nucleus of the continent, and the dwarfed and shrunken representative of which we find in the northern portion of the Gulf of Mexico to-day.

At the end of the Lower Silurian age, a low fold had entered the State at its southwestern corner, advancing from Tennessee and Kentucky to the northeastward. It is known as the Cincinnati Axis.

The gradual growth and extension of this axis are facts of fundamental importance in the subsequent geological history of the State. It was advancing slowly through Upper Silurian and early Devonian

time, but it suffered a partial relapse during the later Devonian period, in which the Ohio Black Shale (Huron of Newberry) was formed. But early in the Sub-carboniferous age it had made a great and permanent gain, and had transformed the western half of the area of the State into dry land. The Berea Grit, a Sub-carboniferous formation, which now extends in an unbroken wall from the Ohio valley to Lake Erie, through the central portion of the State, is as well-marked a shore line as was ever left by a retreating sea.

The Cincinnati Axis had now become connected, virtually at least, with the northern continental nucleus, and the subsequent history of the eastern half of the State depends upon the joint advance of these land masses, the western and northern borders of the gulf. Both seem to have extended themselves in the same manner by a slow and nearly uniform rise of the border, accompanied by a corresponding movement of depression in front of the advancing land. The result was the gradual expulsion of the sea from this northern arm of the gulf, and it also followed that each new and well-marked shore line must be found interior to that which had preceded it. Thus, for example, the western outcrop of the Shenango sandstone, the Waverly Conglomerate of Ohio, which marks a shore line, and which belongs 300 to 500 feet above the Berea Grit, is found between 10 and 20 miles to the east, and south of the western outcrop of the Grit. In like manner the lowest coal seam was formed around the margin of a sea which had left those earlier formations behind it. The later coals never extended over the outside margins of the earlier swamps. If there had been continued subsidence without this corresponding elevation during the growth of the coal seams, the later seams would occupy constantly widening areas, but the contrary is true. The outcrop of the horizon of the Sharon coal passes through a circuit of 13 counties, and its length, exclusive of the sinuosities due to erosion, will not fall far below 275 miles. The outcrop of the Pittsburgh coal passes through 9 counties, with an approximate length of 175 miles. At the time when the Sharon coal was forming, the area of the gulf in Ohio was not less than 10,000 square miles. In the time of the Pittsburgh coal, the area was reduced to less than 6,000 square miles.

All of the coal seams of Ohio below the Freeport horizon, and a number above, appear to have been formed as marginal swamps around the border of the sea. The earliest suggestion of this view seems to

have been made by Prof. J. J. Stevenson. It is now established that the coal vegetation grew where we find it. A coal seam is literally a buried swamp, a fossil peatbog. The facts illustrating this mode of origin, for the Sharon coal in particular, have been set forth with great clearness by Newberry in his reports upon that seam. But there are equally convincing facts in regard to many of the other seams, all of the proofs, for example, that the sea was near at hand while these seams were growing.

It is not an uncommon thing to find a coarse sandstone, and sometimes a decided conglomerate, directly overlying a seam of coal. But strong currents would be required for the transport of this kind of material, and such as belong to the sea.

The Mercer coals, the Brookville coal in part of its Ohio development, and the Upper Clarion coal are all covered by marine limestones, charged with the various forms of the life of the Carboniferous seas.

These limestones very often come directly down upon the coal, making the roof of the seam. These facts certainly show that the sea was near at hand when the slight depression occurred that terminated the growth of the coal swamp.

So also the presence of bowlders in the coal requires the neighborhood of the sea to account for them. There is in the Geological Museum of the State University, at Columbus, a bowlder of metamorphic sandstone, apparently derived from the Cambrian rocks of the Appalachian border to the southward, that was taken from the thick coal at Shawnee, just above the second slate. The coal was normal in all respects above it. The bowlder weighs not less than 200 lbs. The surface of the bowlder appears *glaciated,* and ice transport would seem almost a necessity for such a block. But this would imply the near presence of the sea. The occurrence of bowlders in the body of the coal is rare, but there are several instances on record in Ohio geology. (See Report of Progress, 1870, p. 78.)

The Freeport coals seem to have had a somewhat different history. Their limestones, as has been already stated, are not distinctively marine. They probably originated in fresh or at least in brackish water. They are charged with but one constant and characteristic fossil, and that is the almost microscopic form *spirorbis.* They may well be termed *spirorbis limestones.* But all the facts point to a freshwater rather than to a marine origin for this fossil.

At this time the floor of the gulf seems to have been brought up nearly to the sea level over a wide area, and it seems probable that numerous islands appeared throughout this area. Around their shores as well as around a main coast line, the coal-forming swamps could grow. The instability and frequent interruptions of the Freeport coals can be understood from this point of view. They nowhere show the continuity of the lower seams. They occur in basins, and not in continuous sheets, with a greater breadth of outcrop than the seams below them. They suggest an archipelago rather than a continental margin. But this period was terminated by the return of the sea in full force. The Mahoning sandstone, coarse and often conglomeratic, makes the roof of the Upper Freeport coal, and it is to the strong invading currents that brought in the sand and pebbles of this formation that the frequent and often disastrous "wants" are due, which occur even in the districts where this seam is at its best.

These are theoretical questions, but they bear directly on practical and economic interests. The amount of coal that the Ohio coal field contains turns, of course, upon the extent of the seams. If we see reason to believe that these lower seams originated in marginal swamps, with the sea near at hand, then of course we abandon the older view that the coal seams extend indefinitely towards the center of the basin. A breadth of a few miles, of a score or so, at most, would be all that could be reasonably expected for any such seam. The earlier and the later seams could no longer be looked for in the same section, and instead of concluding that the amount of coal, underlying any given county or town in the coal area, depends on its proximity to the center, and deepest portion of the basin, it would be nearer the truth to make the amount of coal *inversely* proportional to such proximity. In other words, we should expect to find the interior of the basin filled with "*terrains mort*"—that is, with dead or unproductive rock.

Almost all of the facts that have a bearing on the question seem to support the view that is here presented.

Not only is there no instance known in the State in which the Sharon coal is *mined* under the outcrop of the Kittanning coals, for example, but there is no instance known in which the Sharon coal has been *found of mineable thickness* directly under a mineable thickness of the Kittanning coals. Not a year goes by which does not bring numerous tests of the facts involved in these statements in the shape of drill

records from various parts of the coal field, but so far the testimony is all in one direction. Claims are sometimes made of discoveries of the lower coal within the limits of these upper seams, but none have yet been substantiated. The 3-feet coal in the New Lisbon well, which has been by some supposed to belong to the Sharon horizon, cannot be below the Lower Mercer horizon. The heavy deposit reported from the Post Boy borings, south of New Comerstown, seems too impure to be taken as a representative of the Block coal, nor is the depth of the deposit what should be expected for this seam.

No argument is made against the possibility of such overlap. The possibility is freely conceded, but the record of every new drilling increases the improbability of these desirable discoveries. The Sharon coal seems to have a heavier cover in Stark county than elsewhere, if the records of borings reported from there prove trustworthy. It underlies the Putnam Hill limestone, according to Newberry, in the northeastern part of the county.

The Freeport coals have already been placed in a different group from the seams below them as to origin, and the fact of their wider horizontal distribution has been pointed out. It is the Lower Freeport coal that is found in the same vertical section with the Pittsburgh coal in the Steubenville region, and it seems probable that it is one of these Freeport seams that has been struck in the Pomeroy Salt Wells. Stevenson reports the Upper Freeport coal as the only Lower Measure seam to be found in the oilbreak of West Virginia.

Furthermore, a coal seam can often be traced toward the interior of the field along some open valley, or by means of a series of test borings. In numerous instances such seams are found to suffer gradual reduction, or frequent interruption, or to completely disappear. The Kittanning coals furnish examples of these facts in the valleys of the Connotton, of Wills Creek, and of the Muskingum. They are traced in all of these cases until they seem verging toward extinction.

The Dip or Inclination of the Coal Measures.

The dip of the Lower Coal Measures has already been referred to, and the general fact that it is light has been stated, but a few additional facts as to this subject will here find appropriate place.

As to the direction of the dip, the facts can be easily stated. In the easternmost counties of the Ohio coal field, it is nearly or in some

cases directly south. A westerly element comes in if we advance to the southeast into Pennsylvania, but as we pass to the westward through the Ohio Coal Measure counties, an easterly element of the dip is soon recognized. This element gradually increases, until on the western boundary of the field it often predominates over the southerly direction, and sometimes completely extinguishes it. The dip of the Ohio Coal Measures is thus seen to range from south or nearly south upon the northern boundary of the field, to east or nearly east on the extreme western boundary, and its predominant direction is southeasterly. For considerable areas, the dip often proves quite constant, and here it is possible to determine the elevation of a coal seam, for example, in some locality where it has not been opened, by calculations based on the dip of the seam, established on its known elevations in the vicinity. It is never safe, however, to trust absolutely to this method of determining the stratigraphical relations of a varied series, for the direction and amount of the dip are often found to change enough in short compass to vitiate any nice determinations founded upon them.

The same inclination in direction and amount is shared by the formations that underlie the Coal Measures in the Ohio basin. This has already been stated, at least by implication, in the earlier pages of the chapter. Not only the Berea Grit and the other divisions of the Sub-carboniferous age, but the Devonian and Upper Silurian formations of Central and Southwestern Ohio as well are all characterized by this monotonous southeasterly dip. The steady elevation of the Cincinnati Axis seems adequate to account for it, the dip being at right angles to the general direction of this line of elevation.

Reference has already been made to the fact that the Coal Measures of Ohio are traversed by occasional folds, low in elevation and gentle in pitch. Their direction is in the main the same as that of the Cincinnati Axis and the Appalachian Mountain system, viz., northeast and southwest. They are generally referred to the time of the great disturbances that followed the Carboniferous age, and which raised so conspicuous a portion of the eastern border of the continent. These folds of necessity reverse or intensify the prevailing dip in their immediate vicinity, but they are after all folds in a series already inclined, and they scarcely break in upon the regularity of this inclination in the large way. The reversed dips which Newberry finds in the Tuscarawas valley and elsewhere are in many cases to be referred to the duplication

of the numbers 5 and 6 for the coal seams already pointed out. When the lines from which dip was to be calculated were run from the Middle Kittanning coal in the Tuscarawas or Connotton valleys to the Upper Freeport coal, as found at the southward, the two seams being counted identical, the 120 to 150 feet between them would of course do something toward overcoming the true inclination of the series. Some of Whittlesey's published triangles of dip are vitiated by his acceptance of the identity that was claimed for the two coals known as No. 6.

Stevenson has pointed out several folds in Guernsey and Muskingum counties, but their pitch is light, and the series very soon resumes its normal inclination after they are passed.

There is hardly a mine in Ohio from which the water inclines to run in any other direction than to the south and east. Sometimes a few acres will be found to lie nearly level, and many little rolls of the bottom will throw the water to the west or north for a time, but the main drains of all the large mines discharge to the southeast, wherever gravity is relied upon to accomplish the drainage. Only one or two exceptions to this rule are known in the case of the large mines. The fact is of great significance in its bearings upon the dip of the strata.

As to the amount of the dip, it may be said that it is much more variable than the direction. Still the limits are not hard to fix.

There are some points, and especially in Eastern Ohio, where the dip rises to 1°, which gives an inclination of 1 in 57 feet, or in other words, about 93 feet to the mile, but the usual limits are between 20 and 40 feet to the mile. Throughout a considerable part of the Hocking Valley, for example, the dip is quite steady at an average of 27 feet to the mile, its direction here being about 65° east of south.

Partings, Roof, Floor and Joints of Ohio Coal Seams.

There are some seams of coal in the Ohio scale that are found without partings or constant divisions of any sort. The Sharon coal throughout the State belongs, as a rule, to this class, and the Lower Kittanning coal in Muskingum and Perry counties furnishes another example. But by far the larger part of our coals have regular and often very persistent divisions in the shape of bands of shale, or fire-clay, or pyrites, or mineral charcoal. When the latter occurs in considerable thickness, it is generally charged quite heavily with pyrites, and goes by the name of "black sulphur." These partings are

often constant over wide areas in thickness, in composition and in their place in the coal seam. They divide the seam into well-marked benches, which are often sharply distinguished from each other in both chemical and physical properties. These benches often constitute, in fact, quite distinct coal seams. But even in the undivided seams there are in many instances considerable differences between the different portions of the seam.

Sometimes, however, the parting will gradually change its position in the seam as the latter is followed through a considerable territory, leaving much more or much less of the coal below it than where first observed. The thickness of these partings varies from a fraction of an inch to 2 feet, but in the large majority of our worked coals, they range from ½ inch to 3 inches. They sometimes furnish the "bearing in" for the miner, and in most cases they facilitate his work in removing the coal so as perhaps to compensate for the extra labor that he is obliged to expend in separating them from the coal that is sent out. They furnish a considerable part of the "slate" that is so frequent a subject of dispute between operator and miner. They are often so characteristic of the seam in position and in composition that they go far to settle questions of geological identity. It will be found that considerable use has been made of these "partings" in the subsequent pages of this and other chapters. They are generally shown under the title *Structure of the Coal Seam.* In addition to these regular partings there are many inconstant layers of shale or pyrites that occur anywhere in the seam.

The roof and the floor of the coal are subjects of great economic interest in the working of any seam. In the Ohio field the normal cover of the seams is shale, and the normal floor or seat of the coal is fire-clay, but in the practical development of the field numerous exceptions are found to occur to both these statements. While shale is the cover of every well-formed seam, less frequently, but still in the case of several quite wide-extended though not very valuable seams, a stratum of limestone makes the roof of the coal.

The sandstone seldom descends to the coal without doing it damage. A deterioration of quality as well as of quantity in the seam is universally associated in the minds of all who are practically acquainted with the subject with a sandstone roof. The coal is generally thinner, more impure, and of shorter grain, and thus harder to mine, wherever the sandstone comes down upon the coal. This descent of the sandstone

gives rise to one of the most serious interruptions and irregularities which the miner meets. The coal seam has often been carried away in large part or entirely by the intrusive currents or streams that brought in the sandstone, and the miner is either obliged to cut long passages through the solid rock to reach the coal that lies beyond, or else to make expensive detours for the same purpose. These intrusive sandstones are termed *horsebacks* in mining parlance. There are several seams that are especially liable to trouble from this source. The Upper Freeport coal, for example, has suffered great violence and loss at the hands of the Mahoning sandstone.

A firm sandstone, separated by a few feet of shale from the coal, gives the most advantageous roof.

The character of the intervening shale is a matter of great consequence as regards both the economy and the safety of the mine. Some shales slake in such a way when the air reaches them that they cannot be held up by posts. They give way and crumble from around the post. Others can be held up without difficulty as long as is desired. It sometimes happens that it is most economical to leave the uppermost bench of the coal as a roof. A black slate often makes an excellent roof. Where there is no sandstone or other firm rock above the coal, we find the "bad roof" that complicates the task of the mine engineer in many of our fields. The cover of the Pittsburgh coal, and also of the Bellaire coal in Eastern Ohio, are examples of this sort. The entries of mines worked in these seams are kept up largely by timbering while the rooms "fall shut" as soon as they are left.

The floor of a coal seam is, as has been already stated, normally fire-clay, but there are numerous exceptions to this order among our Ohio seams. The Sharon coal in some portions of the Massillon field is often underlain by a foot or two of a hard rock, comparable to the ganister that makes the seat of some of the English coals. The pick brings fire with every blow. The Pittburgh coal of Belmont county has for the most part a black slate floor, and no fire-clay. The Diamond seam at Linton has no fire-clay. A layer of cannel makes the floor of the main coal here, and cannels, as Newberry and others have shown, are, as a rule, without underlying clays.

The amount and quality of the fire-clay floor is connected in important ways with the economical working of a coal seam. Some clays will slake as the air reaches them, "throwing the track" by their

expansion, and interrupting the drainage. The whole working of the seam may be affected by this one condition. If the clay has this tendency to "creep," the coal must be mined in small rooms. When workings are abandoned, they are soon closed by an apparent rise of the floor. The size of the pillars, left to maintain the entries, depends on the bottom almost as much as upon the cover. When the bottom is solid, from the clay being thin or wanting, the pillars and ribs are greatly reduced in section. Two or three yards square are now adequate to the work for which 8 or 10 yaids are required under other conditions. These facts have a very important bearing on the amount of coal that can be taken out of the mine.

"Clay veins," one of the most serious drawbacks to mining in many fields, are connected with, and proceed from the fire-clay floor. They seem to have been formed in the earlier stages of the history of the coal seam, by some inequality of pressure or resistance, whereby the bottom clay was forced in thin sheets through the hardening coal, destroying its continuity, and contaminating it with foreign matter. The "grain" of the coal is often affected for a number of yards on both sides of these "spars," as they are termed. The miner is thus made aware of their proximity some time before they are reached, by the unkind working of his coal. None of the seams that are extensively mined are without clay veins, but some are confused and interfered with by them much more than others. The disturbance will often be localized in a small part of a single field.

The "grain" of the coal is but another name for the dividing planes or joints that intersect it. Coal, as is well known, furnishes an excellent illustration of *joints*, a phenomenon common to all rocks. The system is particularly clear in our bituminous coals.

The leading or master joints make the "face" of the coal; the secondary joints are called the "ends" or "butts" of the coal. These joints the engineer expects to follow in opening the mine. The entries are either "face" or "butt" entries, as a rule, and the coal is then said to be worked "on the square," but sometimes, owing to the topography or boundaries, the entries are run "quartering." The miner's work is greatly facilitated by following the faces and ends of the coal. The directions of these joints are quite regular for large areas. In Ohio the main joints or faces of the coal, as indeed of all the other rocks of the scale, bear a few degrees east of north. The "ends" are approximately at right angles to the face.

In some of our coals, especially in the Massillon field, the joints, though well defined, are close and do not readily release the coal, and consequently a larger proportion of powder is used here to free the coal than in any other Ohio field. The miner often calls these planes of division the "slips" of the coal.

When for any reason the regularity of these joints is interfered with, the "grain" of the coal is said to be "short," or "crooked," or "curly," and generally the labor of mining is increased, sometimes to a notable extent, by such irregularity.

When the main joints are well developed, and the secondary joints less perfectly, we have a "long-grained" coal. This term is also used for slaty or inferior coal in some parts of the field. The Upper Freeport seam gives a good illustration of the former case throughout Eastern Ohio. Its faces are bright and clean, and the coal splits naturally along them in blocks from 6 to 18 inches thick, but the end joints, though present, do not so thoroughly divide the coal, and the consequence is that we have the approximately monolithic structure that characterizes the leading fields of this coal, viz., Salineville, Dell Roy and Cambridge. The coal tends to mine in oblong rather than in cubical blocks.

More detailed statements will be made upon these topics in connection with the description of the different seams, and especially in the chapter upon the mining of coal. These condensed and general statements are necessary to make the accounts of the several fields readily intelligible.

Classification of Ohio Coals.

All the coals of the Ohio series belong to the bituminous division, but they are further divisible into three well-marked groups, viz.: (1) Open burning coals; (2) Cementing coals; (3) Cannel coals; the first two of which are sometimes termed cubical coals.

Newberry describes these divisions as follows (vol. II, pp. 122–3–4):

"The first variety enumerated includes those that do not coke and adhere in the furnace, and such as can be used in the raw state for the manufacture of iron. They have generally a distinctly laminated structure, and are composed of bituminous layers, separated by thin partitions of cannel or mineral charcoal, materials which do not coke.

Hence, the bitumen in them, relatively small in quantity, is held in cells, and cannot flow together so as to give the mass a pasty, coherent character. In Ohio the lowest stratum of this series . . . is generally a furnace coal. As it occurs in the Mahoning Valley, it is a type and standard of the class to which it belongs, and is one of the best furnace fuels known. . . . . Coal No. 6 . . . has locally this open-burning character."

"The second class or cementing coals are such as have few partitions, but show upon fracture broad surfaces of pitch-like bitumen. These, to a greater or less degree, melt or aggultinate by heat, forming what blacksmiths term a hollow fire. This property causes them to choke up the furnace, and arrest the equal diffusion of the blast through the charge; hence, they cannot be used in the raw state for the manufacture of iron, but must be coked. This process of coking consists in burning off the bituminous or gaseous portion, which leaves the coal in the condition of anthracite, except that as this change is effected without pressure, the resulting material is cellular and spongy. Coals of this character when free from sulphur, their great contaminating impurity, are used for the manufacture of gas, the volatile portion driven off in the retorts serving the purpose of illumination, while that which yet remains is coke, and may be used as fuel. By far the greater portion of our coals are of the coking variety. . . . .

"The cannel coals are more compact and homogeneous in texture, and contain a larger percentage of volatile matters than the others; also, the gas they furnish has higher illuminating power; hence, they would be used to the exclusion of all others for the manufacture of gas, but that the coke yielded by them is of inferior quality. They are, therefore, chiefly employed as household fuel, for which they are specially adapted, and in small portions for enriching the gas from inferior varieties."

To these statements it may be added that the last-named division has but very little economic value in Ohio at the present time. In working the regular coal seams, small deposits of cannel are sometimes struck, which take the place of a part or even of the whole of the seam for a limited extent. When thus situated, an effort is often made to dispose of the cannel that is obtained in this way, and a little of it is occasionally pushed into the market, but there is no regular and reliable

demand for Ohio cannel at the present time. There are several considerable deposits that are known in the State, but not one of them is now worked on its own account.

The division between the open-burning and the cementing coals of the State is to a certain extent a geographical one. From Perry county, southward and westward, all of the coal that is now mined is open-burning, except the product of a single mine. From the same boundary, northward and eastward, nearly all of the coals, with the exception of the Sharon seam, belong to the cementing variety, though many of them possess this property in but a moderate degree.

The differences between these several classes of bituminous coals are not shown in the results of chemical analysis. In other words, a knowledge of the chemical composition of a coal does not enable us to refer it to one or another of these several varieties. As a rule, the cannels range higher in ash than the cubical coals, but among the latter there are very many gradations in this respect. There is no known relation between the amount of volatile matter in a coal and the coking property, whereby a coking coal can be separated from an open-burning coal on the grounds of analysis alone.

It has been suggested that the coking or open-burning properties of coals are dependent upon differences in the vegetation from which they are respectively derived. The suggestion is plausible and interesting, but such connections have not yet been demonstrated.

Composition of Ohio Coals.

The results of chemical analyses of Ohio coals, as ordinarily stated, comprise the following elements, viz.:

1. Fixed carbon.
2. Volatile combustible matter.
3. Moisture.
4. Ash.
5. Sulphur.

The first two elements are those upon which the value of the coal depends, and the terms by which they are designated go far to explain themselves. The fixed carbon is the part which remains after the coal has been raised to a bright red heat; the volatile combustible matter is the part which escapes as gas under the above named condition, the moisture of the coal having been previously expelled. While the

amounts of the several chemical elements and compounds in any coal are, of course, a definite quantity, the amounts reported in analyses as fixed carbon and volatile matter depend to a certain extent upon the details of the methods used in determining them. The method used by the Chemist of the Survey, Professor N. W. Lord, gives somewhat lower figures for the fixed carbon of our coals than those that have been generally accepted hitherto. A synopsis of the methods employed will be found in a later portion of this volume.

The remaining substances reported in our analyses are moisture, ash and sulphur. While these substances are never absent from coal, they are found in it in very different amounts, and, speaking generally, any increase in proportion above the lowest figures that are found, is to be counted as a detriment and drawback in the ratio of such increase. But even here the results af analysis cannot be used as an absolute guide in determining the value of any particular coal. Other things being equal, the smaller the amount of ash, sulphur and moisture, the better the coal, but the saving clause is of wide extent and application. The physical character of the coal is involved in it, and it is often true that firmness and tenacity in a coal will more than compensate in the general judgment for some inferiority in composition.

Chemists are not entirely agreed as to the proper method of determining the absolute efficiency of a coal. The result of many determinations has seemed to make the heating power depend upon the fixed carbon alone, but other experiments are construed as proving that the heating power is proportioned to the total amount of carbon of the coal, that of the volatile matter being included with the fixed carbon. It is no doubt true that the amount of fixed carbon in a coal furnishes an approximate gauge of its absolute heating power.

There are few coal mines in the State in which good specimens of coal cannot be found, and there are none that do not contain some coal of inferior quality. The instances are very rare in which the quality of an Ohio mine can be safely determined by the analysis of a single, so-called average specimen. But many of the analyses now current were made from single pieces, and often from small ones at that, selected to show the very best quality of the mine. The results of such analysis are, as a rule, altogether too favorable, and they are not to be depended on for practical guidance. They naturally represent the best portions of their respective seams, but for practical service, a knowledge of the

worst part of the seams would often be more valuable than a knowledge of the best. The average is what is demanded for practical guidance.

Two plans have been followed in selecting samples for the analyses to be here reported. In one of them, the aim has been to secure a representation of the seam just as it is mined, by taking a cubic inch or less of coal from every inch of height of the seam, the partings and other rejected portions being, of course, omitted.

It can be urged against this method that the seam is sampled at but one point, and that but one room is in reality tested. This is true, and analysis of the coal from other rooms of the mine will often vary considerably from the results obtained, but the aim has been to take the samples from rooms where the coal is approved, and as a consequence, the figures published will be somewhat more favorable than the total output of the mine would deserve.

In one instance, an unexpected result was reached. Three sets of samples were taken, one of the whole seam, sampled as above described, one of the general output by the method next to be given, and one of a block selected by the manager as the best coal of the mine. The first set of samples showed the best coal, and the selected block was the poorest of the three. In selecting the samples for the first result, all the slaty partings that were said to be rejected by the miners, were thrown out, but it is probable that in the general output a good many remain. The inferiority of the selected sample only shows how little reliance can be placed on even a well-trained eye in estimating the nicer points of quality in a sample of coal.

The second plan was to take samples from the bank cars as the coal came out, or from the loaded railway cars, the specimens being taken from a large number of blocks, never from less than 50 blocks, and often from as many as 100. This method was counted on the whole most satisfactory, and was used in a great majority of instances.

In any case, to fairly determine the average composition of a particular coal seam, or of a particular mine is a more laborious undertaking than we have been wont to consider it. A single analysis of any sort does not go far towards determining it, but least of all is it trustworthy when the sample analyzed is the best that the mine produces.

A necessary result of these methods of selecting the samples has been to show a considerably larger proportion of ash and of sulphur in

our coals than has been charged to them hitherto. The results thus obtained can be fairly compared only with each other, or with analyses made on the same principle elsewhere. Great injustice would be done by setting the composition of nicely selected and exceptional samples over against these general averages. But the method has justified itself in various ways; especially, it has revealed for the first time, an individuality on the part of several of our leading seams, as far as chemical constitution is concerned. There is shown to be a normal composition for each of these several seams that is as constant and as widely extended at least as the physical characters by which it is distinguished. For example, the two coals that are known in our geological reports as No. 6, viz., the Middle Kittanning and the Upper Freeport, are clearly distinguishable from each other throughout Eastern and Central Ohio on chemical grounds. The fixed carbon of the former seam does not rise to 50 per cent. in a single instance in all the analyses that have been made of the seam between Mahoning and Perry counties, while the same element in the Upper Freeport coal of the same territory does not in one instance fall as low as 50 per cent. The average of the latter is 53 per cent., and of the former 48 per cent. The volatile matter of the Middle Kittanning seam in the same district does not in one instance fall below 40 per cent., while in the Upper Freeport coal it does not once rise to 40 per cent.

All of the facts bearing on these points will be made apparent in subsequent pages of this report.

The amount of water in our coals varies between 2 and 9 per cent., but a few examples will be found that fall below the smaller limit. The largest regular percentage of water is found in the excellent coals of Jackson county. There seems to be quite a constant proportion in particular coals, making a characteristic feature.

As to ash and sulphur, but few general statements can be made. The details of analysis must be studied to obtain the significance of these important elements in our several coals. The percentage of sulphur falls below 1 per cent. in our best coals, ranging between .6 and 1 per cent., but in many seams that are still highly esteemed for varied uses, it rises to 3 per cent. and upwards. In comparatively few does the average fall below 2 per cent., and some coals are used that contain 7 per cent.

There is but little coal in Ohio markets that yields less than 4 per

cent. of ash. The products of some of the choicest mines will fall to 2 per cent., or even to 1½ per cent., but there is no district that can live up to this rate. The average ash of the best coals that supply the State at present exceeds 5 per cent.

Uses of Ohio Coals.

A few general statements as to the chief uses of Ohio coals will be given here, in order that the detailed statements that follow may be seen in their proper light.

The following list shows their more important applications:

1. Household use.—Grates, stoves, furnaces.
2. Steam production. { In locomotives. In stationary engines.
3. Iron smelting coal.
4. Coke manufacture.
5. Rolling mill fuel.
6. Gas making.

1. For household use there is no fixed and common standard. Widely separated varieties are used with apparently equal acceptance in different sections of the State. The rich, cementing coals of the Pittsburgh district have long been the chief supply of the Ohio Valley, and here they hold their ground against all competitors.

The open-burning coals of the Mahoning and Upper Tuscarawas Valleys are the standard fuels of Northern Ohio. Through Central Ohio, several distinct varieties have each the decided preference in as many distinct fields. The most accessible coal will generally be used by each section, and acquaintance with the character of this particular fuel will often lead to its being retained, even when competing coals of intrinsically higher, though different quality, reach the market.

There are, however, some general considerations by which the degree of adaptability of our several coals to domestic use can be determined. For this, as indeed for all other uses, low percentages of ash and sulphur (pyrites) are desirable, as it is to these elements that the production of "clinker" is due. It must also be free from slate and "bone." Furthermore, the coal must ignite easily, and still must hold the fire at least moderately well. A fairly high percentage of carbon is of course necessary. The less smoke and soot it makes in burning the better. In addition to these points, its physical properties must also recommend

it. It should be clean and bright, and it should also have strength enough to bear all necessary handling without excessive breakage.

According to such a standard, the coal of the Sharon seam, and especially in the Massillon district, would be entitled to the first place, but it would be followed close by several other coals. There are many large coal fields, and some entire seams that make no attempt to enter this market.

2. High quality in a coal will tell upon its efficiency in the production of steam as promptly and certainly as in any other use, but poorer quality is less objectionable and offensive here than elsewhere. Chemical and physical properties that would wholly exclude a coal from certain of the higher uses may not interfere with the wide and acceptable use of the same coal in the production of steam. A coal that mines small, or that is too tender to bear handling, is ruled out of the market for domestic use, but such points count little or nothing against it as a steam coal at the present time. Both locomotive and stationary engines have been lately adjusted so as to successfully use the smaller grades of coal, nut, pea, and even slack. The yard engines of many railroads, and the freight engines of some, do all their work on pea coal and slack. This great saving of fuel, often derived from the best part of the seam and entirely lost hitherto, is a matter of great importance to the coal fields and the State as well.

The "strength" of the coal, or its absolute heating power, seems a matter of more consequence in a steam coal than the nicer points of composition.

All the coals of the State, from the purest and best, to the seams of lowest quality, do duty as steam coals, but there are some seams that are practically limited to this service. The Upper Freeport coal is an example of this class. It is one of the most important seams of the Coal Measures, but every year fixes its character more definitely and exclusively as a steam coal. Its high percentage of fixed carbon ensures its efficiency, and its tenderness under handling works less against it here than in most other applications.

Open-burning and cementing coals are used promiscuously by the same railroad often, but probably not without some disadvantage. Each coal has its own behaviour on the grate-bars, and each gives better results when treated in one way than in other ways. The neglect to study and recognize these "personal equations" of the different seams,

vitiates or even nullifies many of the practical tests to which the coals are subjected. Unless each coal has been so treated as to ensure its best results, the so-called test is unfair and deceptive. One locomotive engineer will complain of a coal that it "smuts the flues." Another will use coal from the same mine without experiencing the slightest tendency to this trouble.

Ash, sulphur and slate that tend to run on the grate and form "clinker," or that accumulate so as to deaden the fire, are the elements that are most obnoxious in our steam coals.

3. For blast furnace use, only the best and purest of our open-burning coals are available in the raw state. There are four fields from which such coals are taken, viz., the Mahoning Valley, the Massillon district, the Hocking Valley, and the Jackson county district. The first of these regions has furnished the type and standard of this class of fuels hitherto, but its day of service in this field has gone by, and it is now almost entirely displaced on its own ground by the great iron making fuel of the Ohio Valley, Connellsville coke. The Massillon coal has not as happy an adaptation to this use as the coal already named, and has never been applied to iron making in the large way. But very little of it is used in furnaces at the present time.

The Hocking Valley coal in its best phases is well adapted to iron manufacture, and a great and growing industry is already established upon it in this connection.

The two seams of Jackson Court House and vicinity, viz., the Shaft coal and the Hill coal, are both largely and successfully used in the furnaces of the district to which they belong.

4. There is but one field of the State in which coal is mined expressly for coking. The small coal and slack of several districts go to the coke ovens, but in Leetonia alone is the whole product of the mines brought to the ovens.* This is the only coke now made in Ohio that is used in iron smelting. The Shaft coal of Steubenville has been largely used in this way in the past, but it, too, has succumbed to the superior quality and lower price of Connellsville coke.

The coke now made in the State is chiefly manufactured from the small coal and slack that accumulate in mining. The impurities of the seam are often gathered here in large amount, and the coke that results shows their presence by excessive ash and sulphur. These cokes are

* The Hammondsville Strip Vein is mined for coking also, but the output is insignificant.

used to but small extent in foundries, and find their main applications in heating purposes where quality is not essential. The use of these waste products in this way is an important step in the line of fuel economy, a topic which our coal producers are just beginning to consider.

The seams used for coking are especially the Freeport coals and the Pittsburgh. No successful manufacture now exists in any other seam, in fact, except in the two cases already noted of the Lower and Middle Kittanning coals, at Leetonia and Hammondsville, respectively.

5. The requisites for a good milling coal are quick combustion, with plenty of flame, together with as much purity as can be secured. The Brush Creek coal, the Freeport coals, and the Kittanning coals furnish the chief supply. Each of these several seams does good service at some point or other in its development.

The Salineville Strip seam (Brush Creek coal), the Steubenville Shaft seam (Lower Freeport), and the Leetonia coal (Lower Kittanning) all enjoy excellent reputation as milling coals. The Pittsburgh and the Upper Freeport seams are also considerably used. The Block coal of the Mahoning Valley is highly esteemed for this use wherever the price at which it can be afforded allows it to be used.

6. For gas making, our native supply is not drawn upon to any great extent outside of the State boundaries. Within these limits several seams are used with a fair degree of acceptance. The Hocking Valley coal furnishes by far the largest supply for this purpose. The inferior quality of the coke produced puts them all at a disadvantage when compared with the Pittsburgh coal.

Preparation of Coal for Market.

Almost all Ohio coal is sorted and cleaned by a process called screening, before it is brought into market. All that is used for domestic purposes is treated in this way, also all that is used in iron making. Until quite recently, all railroad fuel has also been screened. A large proportion of it is still prepared in this way, but there is a growing tendency on the part of railroad companies to either use the coal as it comes from the miner's pick, which is technically known as the "run of mine," or else to throw together two or more of the several grades of coal that have been sold separately hitherto.

There are two grades of coal supplied by almost all mines, and

three grades from many. These are respectively designated lump or round coal, nut coal, and slack. The first commands the highest price, the last is often valueless, but within the last few years, the slack of certain seams has come into demand for various purposes, and a large quantity is now finding its way to market. From the slack is also derived the grade of coal called pea coal, which a few mines are furnishing.

The process of screening consists in passing the coal as it comes from the bank cars over one or more inclined screens on its way to the cars, boats, or wagons by which it is to be transported to market. There is no general system in force in the process of scieening. The length and width of the screens, the angle or pitch at which they are placed, the space between the bars, the width and shape of the bars, all these vary between wide limits in the different portions of the field, and even in different mines in the same district. The miner is paid in most of the districts on that portion of the coal only that passes over the screen, or in other words on lump or round coal, which is also called clean coal. The varying characters of the seams, the differences between different mines in the same seam, and different portions of the same mine, all these elements combine with the facts already noted as to the varying dimensions of the screens to make the question of wages for mining a complicated and troublesome one. The screens are a fruitful source of discord between the mine operator and the miner.

There is a rapidly growing appreciation of the second grade of the coal product, *i. e.*, the nut coal. This grade results quite largely from the operation of "bearing in" upon the coal seam, or undermining it. In a large number of instances, the best portion of the seam occurs in the "bearing in" bench, and thus the nut coal often contains the choicest fuel that is produced from the seam. The lump coal must generally be reduced to smaller size before it can be used, but still the popular demand has hitherto been for large coal, and great quantities of the smaller sizes have been utterly wasted. The arrest of this waste, and the bringing into use of all the products of the mine are steps of great interest to the State at large.

The nut coal is run with the slack in some fields, enriching this latter element so as to make it a fully marketable product, which still goes under the name of slack.

Within a few years, two new departures have been made in the dis-

position of the slack in several districts. In some the slack is sifted or washed in revolving screens, by which the dust is removed, and the resulting fuel is known as pea coal. This finds market for use in stationary engines, and for other like purposes. The second of these new methods consists in coking the slack. Mention will be made of both processes in connection with the several districts in which they are used.

The statements here made are sufficient to render intelligible the details that will be found in subsequent pages upon the points involved in this brief discussion.

Proportion of Coal Lost in Mining.

This very important subject is directly connected with and dependent upon many of the points that have been already treated, but no proper nor profitable average can be given as to the results of coal mining in Ohio at the present time. The proportion of the coal gained in mining is increasing in most districts of the State, owing to better methods of mining, and better demand for the smaller coal. The empirical rule that gives 1,000 tons of coal to every acre for each foot in thickness of the seam, doubtless expresses the actual result in a large number of instances, but better figures are now obtained in many sections, as will be hereafter shown, and far better results are certainly attainable in almost all of our districts.

The specific gravity of our coals ranges for the most part between 1.24 and 1.34. Assuming the mean, or 1.29 as the average, and this figure is very near the truth, every acre of such coal will contain for each foot in thickness 1,752 tons of 2,000 lbs. The miner's estimate, as embodied in the rule above referred to, shows that he is content with securing four sevenths, or a little more than half, of the coal that the seam contains. The best foreign practice is far in advance of such results. In the Bristol coal field of England, it is calculated that 1,500 tons to the foot are won for each acre, the entire loss in mining being reduced to one-tenth of the seam. The best practice that is fairly well verified in Ohio gains two-thirds of the coal, and the cases in which this is done are very rare. More than this is claimed in many mines, but it is probable that, if examined, such claims would be found to be untenable.

GENERAL CHARACTERISTICS OF THE SEVERAL COAL SEAMS.

1. The Sharon Coal.

Synonyms.—Coal No. 1, Block coal of Mahoning Valley, Brier Hill coal, Massillon coal, Wadsworth coal, etc., Jackson Shaft coal?

This seam as it occurs in Northeastern Ohio has been quite fully described by Newberry, and all of its chief peculiarities have received mention. (Rept. of Progress, 1870, pp. 26–27–28. Geol. of Ohio, vol. II, pp. 132–133–134; vol. III, pp. 139, 140, 157 et al.)

It is the lowest of the workable coal seams of the State. Where the Sharon Conglomerate occurs in the same section with it, the coal lies but few feet above the conglomerate, and where the latter is wanting, the coal rests directly upon the Waverly group. Its normal cover is the Massillon or Lower Connoquenessing sandstone, the second sandstone of the Conglomerate series. From this it is generally separated by 10 to 20 feet of ore-bearing shales, the Sharon shales of Pennsylvania.

It always lies upon an uneven floor, in basins of comparatively small extent. The area of but few of these basins reaches 200 acres of unbroken coal, but in a few instances larger bodies have been found. Where the seam has had good fortune, its thickness ranges from 4 to 6 feet. It occasionally gains a foot upon these measurements, but it does not hold the increase long. It is everywhere a seam of "swamps" and "hills," the latter rising 20, 30, or even 40 feet above the lower and more productive portions of the seam. In ascending these hills, the coal rapidly loses height, as a rule, and frequently entirely disappears.

The seam, at its best, is of high quality. It is, in fact, the standard of quality among the open-burning coals of the northern Appalachian field, and it commands a higher price in all the markets that it reaches than any other coals of the same class. But there are not only distinct varieties of it in the several divisions of the field, as for instance, the Youngstown, Massillon, and Jackson districts, but even in any one

field, as the Youngstown region, there are many gradations in quality. Relatively poor coal—that is, coal high in ash and sulphur—goes to market under the name of Block coal, and sells for a higher price than the Hocking Valley coals, for example, the best of which are nearly equal to the best of the Block coals, and which, taken as a whole, are far better than these poorer varieties of this lower seam.

The Sharon coal is mined in the following named counties, which constitute the northeastern corner of the coal field of Ohio, viz., Mahoning, Trumbull, Portage, Summit, Stark, Medina, and Wayne. In Southern Ohio, a single field of small extent, in Jackson county, is referred to the same horizon.

The acreage of the seam is, however, small, and a considerable part of it is already exhausted. The northernmost area, viz., the Mahoning Valley, is verging to exhaustion. The Massillon district has probably not yet attained its highest development, though most of the first and best known mines have been mainly worked out.

The better coals of the seam contain between 52 and 56 per cent. of fixed carbon. The volatile matter varies between 35 and 39 per cent. The ash is variable, but the average will not fall below 5 per cent. The amount of sulphur is a little less than 1 per cent.

2. The Quakertown Coal.

Synonyms.—Coal No. 2, Wellston coal? Jackson Hill coal?

This seam can scarcely be said to deserve a name or place in the Ohio column. Of the 33 counties in the State in which coal is mined, there are but a few square miles in a single county in which coal is actually worked in the large way at this horizon. Even here, the claim is not altogether free from question, but it seems probable that the Jackson Hill or Wellston coal is the proper representative of the Quakertown seam of the Mahoning Valley. The Wellston coal occupies a small area near the center of Jackson county, but though embraced within narrow limits it is a seam of great value. It contains less ash than any other coal found in the markets of the State, and in all respects it stands approved as a fuel of great excellence. It is always high in moisture.

The Elk Fork coal of McArthur is probably the equivalent of the Wellston seam. It is not now worked, but several openings have been

made in years past, and an excellent character for the seam established. There are many traces of a coal seam between the horizon of the Sharon coal and the Lower Mercer coal throughout this portion of the State, but it is very rare that a thickness suitable even for local mining is found. In Hocking and in Perry there have been opened at one time or another a few local banks, but none of them are kept open at the present time.

The Strawbridge Cannel of Holmes county has been referred to this horizon by mistake. This seam is on the Upper Mercer horizon.

The horizon of the Quakertown coal is 75 to 100 feet below the Lower Mercer limestone, which would place it 50 to 75 feet above the Sharon coal. The interval in Jackson county are greater than this.

3. The Lower Mercer Coal.

Synonyms.—Coal No. 3, Coal No. 2, of Mahoning county, the Blue Limestone coal, Flint Ridge Cannel, etc.

This seam has a distribution coextensive with the margin of the Coal Measures in Ohio, but its value is not proportioned to its extent. Though occurring in 13 counties of the State, and though belonging to one of the most conspicuous and best-known horizons of the Coal Measures, it is worked for railroad transportation in but a single county, viz., Mahoning, and here in but a single small mine. It is but very sparingly mined even for neighborhood use throughout the State. In Holmes county a single mine is opened and worked in this seam. In Hopewell township, Muskingum county, there are a number of mines opened, that meet quite a large local demand, and in Hopewell township, Licking county, the well-known Flint Ridge Cannel represents the horizon.

Many attempts have been made to mine this seam in Perry, Hocking, and Vinton counties, and several neighborhood mines are now in operation in the two last-named counties, but all attempts to find a coal at this horizon that can compete in the general market with approved fuels have proved unsuccessful. The most persistent and expensive undertakings of this kind have been made along the line of the Marietta and Cincinnati Railroad, in the neighborhood of Zaleski. Where the seam has thickness enough to warrant mining, it is too impure to find sale.

There is no general character of the seam throughout the State,

aside from the fact that it is always an open-burning coal. As to amount and color of ash, as to percentage of sulphur, as to the structure and thickness of the seam, no general statements can be made. Many seams of coal seem to have a normal thickness, which is probably related to the duration of the period in which their materials were accumulated. Wherever the seam has had good fortune, this thickness is attained, but there are no such facts apparent in connection with the Lower Mercer coal. Its thickness in one locality gives no warrant for opinion as to what its thickness will be in another.

4. The Upper Mercer Coal.

Synonyms.—Coal No. 3*a* (sometimes Coal No. 4), Coal No. 3, or Bruce coal of Mahoning county, Strawbridge Cannel of Holmes county, Bedford Cannel of Coshocton county, Newland coal of Vinton county ?

This seam is scarcely less widely extended than the one last described, and is, on the whole, a much more valuable deposit, and yet it is nowhere mined on a large scale at present. There is a single field which is ready to furnish the basis of a considerable business whenever railroad transportation shall be provided for it. The field referred to is the Bedford Cannel district of Coshocton county. In Mahoning county, in the vicinity of Canfield, quite a large local supply is furnished by the Upper Mercer coal, which is there known as the Bruce or Infelt coal. It is quite weak in its development in Stark county, but in Tuscarawas and Holmes it is worked in a few neighborhood mines. In the last named county it becomes the Strawbridge Cannel seam, which was made the basis of a large mining scheme a few years ago, but which was never pushed through to a successful issue. The seam acquires its largest volume, and perhaps its greatest value in the adjoining county of Coshocton, where it is known as the Bedford Cannel coal, to which reference has already been made.

In Muskingum, Perry, and Hocking townships, the seam is universally present, but it is generally thin, rarely reaching a thickness of 2 feet. Its quality is, however, often good, and a little of it has been mined at many places. In the central parts of Vinton county, it again attains a good volume. It is known in the neighborhood of McArthur as the *Newland coal.* It reaches a thickness of 5 feet for a small area, part of the seam being cannel. To the southward the seam is very often a cannel coal. It makes the Milton township Cannel of Jackson

county, and the Webster Cannel of Scioto county. Many neighborhood mines are opened in the seam through these districts.

Through the southern portion of the State, it is parted from its limestone by an interval ranging from 12 to 40 feet; the limestone itself being for the most part replaced by a block iron ore.

5. The Tionesta Coal.

Synonyms.—Coal No. 3*b* of Report on Hanging Rock District, vol. III; Wartman coal, do; Bolivar coal of Stark and Tuscarawas counties.

This seam is less reliable as a geological element than the Mercer coals which have been last described, but still it is found in numerous sections throughout the entire field. It is mined in Mahoning, Stark, Tuscarawas, Holmes, and Vinton counties, and to a little greater extent in Tuscarawas than elsewhere, though even here its yield is insignificant. Its position is 10 to 20 feet above the Upper Mercer limestone or its representative in Southern Ohio, the Franklin Furnace Block ore (Main Block ore of the Ohio Valley). Its largest measure is 5 feet, but this thickness is rarely reached. The seam is of but little value in Ohio.

6. The Brookville Coal.

Synonyms.—Coal No. 4 of Stark county; Gray Limestone coal; Upper Limestone coal; Winters coal of Vinton county; Flint Vein, do; Conway coal of Lawrence county; Coal IIIc of Report on Hanging Rock District, vol. III.

This is a much more valuable seam than any that we have found since leaving the Sharon coal, or Coal No. 1. A question must be admitted as to the equivalence of the Brookville coal of Pennsylvania with the Gray Limestone coal, or Coal No. 4 of Newberry, from the fact that no limestone is reported in the Pennsylvania sections as accompanying the former seam; but the Gray Limestone coal of Stark county holds the exact place and relations of the Brookville coal. If the two coals are not one and the same seam, then the Brookville coal has no representative in Ohio, and the Gray Limestone coal is without representation in Pennsylvania, a conclusion that no one acquainted with the demonstrable continuity of the remaining seams of the series will be prepared to admit.

It will be remembered that the Putnam Hill limestone dies out in Mahoning county, as it is followed eastward, and in Perry county, as it

is followed southward. Its horizon can be followed with certainty to the southward, after the limestone has disappeared, but the drift-covered region in which the limestone terminates at the eastward is less favorable for geological examination, and no better proof as to the continuity of the horizon can be furnished than that already given in chapter I. The facts there detailed certainly give a high degree of probability to the conclusion that the Brookville coal in its westward passage takes a limestone roof, and becomes Newberry's Coal No. 4 of Stark county, and that conclusion is adopted and used in this report.

This seam is at its best in Stark county. It is struck in the northeastern quarter of the county in several small mines, but it is on the western side that it attains its largest development. The Valley Railroad passes through the heart of this field, and a number of well-equipped mines of the limestone coal are now in operation along its line.

The seam shows a maximum thickness of 6 feet. It is fairly steady, and a part of the seam is of good quality. It is chiefly used as a steam coal. Its specific gravity is somewhat high, owing to a large quantity of ash in the lower bench. The Putnam Hill limestone makes its roof, resting in many instances directly upon the coal.

Throughout Tuscarawas and Coshocton counties, the seam is generally thin, and no considerable mines have anywhere been opened in it, but in Newcastle, Bedford, and Jefferson townships of the latter county, the seam reaches a maximum of 4 feet, and is opened in many country banks. The chief local supply of these townships is derived from it. In Holmes county also, there are several neighborhood mines opened in the seam.

In Muskingum county the seam has occasionally been worked in a small way. A mine has recently been opened in it in Zanesville, in which the coal falls below 3 feet in thickness. In Perry county and also in Hocking the seam is not worked so far as known, but though thin it is universally present as far as the limestone extends.

In Vinton county it again acquires mineable thickness, and it is quite largely worked for local supply in the vicinity of McArthur, where it is known as the *Winters coal.* It rises to 4 feet in thickness, and its quality is fair. It is associated with beds of flint in some parts of the county, and at several points it has a *flint parting* in the middle

of the coal. From the latter fact it is known as the *Flint Vein* in a portion of the county.

The seam is mined in Lawrence county in a small way under the name of the Conway coal.

The coal of this seam, so far as known, is everywhere of the open-burning variety. Aside from this fact, no general description of the seam can be given. Its ash is sometimes white and sometimes red in color, and is never very low in proportion. Various degrees of strength in the coal are shown in the several fields in which it is most largely worked.

7 and 8. The Clarion Coal—Lower and Upper.

Synonyms.—Limestone coal of Jackson and Vinton counties, Coal No. 4 of Mahoning county, Coal No. IV*a*, Report on Hanging Rock District, vol. III.

Under the above designation the Clarion and Scrub Grass coals of Western Pennsylvania are included. Both seams fail for the most part in all of the northern border of the Ohio field. In Perry county, one of them is found 16 inches thick, at New Lexington and vicinity. It makes no increase of volume until Vinton county is reached, but there it thickens into a workable seam, which has great steadiness and value throughout Vinton and Jackson counties. It disappears again in Lawrence county, and is scarcely found at all south of the Ohio River. In the district of its best development, it is the main reliance for fuel and for the production of steam. It is known as the "Limestone coal," from its close association with the Ferriferous limestone. This stratum makes the roof of the coal in many instances, but sometimes a few feet of shale intervene between it and the coal. The maximum interval observed is 18 feet. There is no clear indication of a division of the seam into two in Southern Ohio. The character of the coal throughout the region referred to is quite uniform. It is a bright, well-jointed, rather weak coal, burning freely, with not an excessive amount of ash, but always high in sulphur. The ash is generally purple in color. In several of these respects it is clearly distinguished from Coal No. 4 of Newberry in the region where this latter seam is best shown, as, for example, in Stark county.

9. The Lower Kittanning Coal.

Synonyms.—Coal No. 5, Stark county and southwestward; Coal No. 4, Leetonia; Leetonia coal; Coal No. 3, Yellow Creek and Upper Ohio Valley; Creek Vein, Hammondsville; Potter's Vein, East Liverpool and Ohio Valley; Clay Vein, East Liverpool and Ohio Valley; Mineral Point coal; Lower New Lexington coal; New Castle coal of Lawrence county

In ascending the scale from the Clarion coal to the Kittanning coal, we have passed the most important and best-known horizon of the Lower Coal Measures, viz., the Ferriferous limestone. The coal now named, and the seam next above it, unite with the limestone to constitute a series as unmistakable and as easily followed as even the Mercer series of which we have already treated. Even where the limestone fails, the coals, one or both, continue in demonstrable persistency and identity, and have much to do in establishing the remarkable order which characterizes the Ohio coal field.

Newberry was the first to recognize the great steadiness and wide reach of these seams. He showed their continuity from Stark county to Perry county, the most important and fruitful service yet rendered to the geology of the Lower Coal Measures of the State. Andrews took up the series at the point where Newberry left it, and traced these two Kittanning coals, Newberry's Nos. 5 and 6, through the leading coal field of Ohio, viz., the Hocking Valley field. He followed them with great sagacity through the various changes and disguises they undergo, as far south as the middle of Vinton county, but here his section was dislocated through a mistaken identification made by one of his assistants. Roy first pointed out the true order from Vinton county southward, and this order was subsequently demonstrated in my report on the Hanging Rock District, in Geology of Ohio, vol. III.

Crandall has followed the series southward into Kentucky for about 50 miles, where these widely extended beds at last disappear.

On the eastern border of the State, the true continuity of the Kittanning coals is for the first time shown in Chapter I of the present volume. They have been traced almost or completely across the State of Pennsylvania by the geologists of the Second Survey. The summing up of these facts would show the Kittanning coals stretching around almost the whole northern margin of the Appalachian field from Maryland on the east to the central part of Eastern Kentucky on the south and west.

The Lower Kittanning coal is one of the most important seams in the Ohio series. It is mined in southern Mahoning county to a small extent. It is more largely worked in southern Columbiana and in Jefferson counties, though here the Kittanning clay that underlies it is of much more importance and value than the coal. The two beds, coal and clay, are often worked together. In northern Columbiana the bed attains great excellence, where it makes the well-known Leetonia coal. The purest and strongest coke of the State is obtained from this seam in this vicinity. It has been worked very largely here for a number of years, and is at present supplying two blast furnaces and a rolling mill. Though made the basis of a large production, the seam is thin, falling below 3 feet throughout all the territory, and being less than 30 inches thick at the point where it is most valued.

Passing westward, we find the coal thin in eastern and central Stark county, but regaining its volume in Tuscarawas county. At Mineral Point it is at its best, for all this part of the State, as to quality and thickness. It disappears very often in Holmes and Coshocton, though there are many small mines opened in it in both counties.

In Muskingum it again becomes important, and is known as the Lower Zanesville coal. It is here 4 to 5 feet in thickness, and of excellent quality. It is largely worked here. The same description will apply to Perry county. Through all of these regions it is in the main an open-burning, white-ash coal. The ash is low as a rule, but the percentage of sulphur is generally high.

In following it still westward, it holds its old character very well, but as it does not exceed 3 feet in thickness, it is completely overshadowed by the Middle Kittanning seam that lies but 20 to 30 feet above it.

It is for the most part quite thin throughout Vinton and Jackson counties, though it frequently rises to 2 or 3 feet in thickness, but in southern Lawrence it becomes a main reliance for a large territory, and is worked in large mines, and is shipped by rail and river. It is here known as the New Castle coal.

Its characteristics can be made out from the statements already furnished. Its fixed carbon is very nearly 50 per cent. through most of the field. At Leetonia, however, it rises high above this figure.

10. The Middle Kittanning Coal.

Synonyms.—Coal No. 6, in Stark county and southwestward; Coal No. 4, in Yellow Creek and the Ohio Valley; Osnaburg coal of Stark county; Pike Run and Dennison coal of Tuscarawas; Coshocton coal; Upper Zanesville coal; Upper New Lexington coal; Nelsonville and Straitsville coal; "Great Vein" of the Hocking Valley; Carbondale and Mineral City coal; Upper Zaleski coal; Washington Furnace coal; Sheridan coal; Ashland or Coalton coal of Kentucky; Willard coal of Kentucky; Coal No. 7 of the Kentucky series (Crandall).

The names given above plainly show that we are now dealing with the most important of the coal seams of the State. It is so closely connected with its companion seam already described, that no discussion of its stratigraphical relations is here required, its place in the scale being 20 to 50 feet above the lower coal. A few general statements as to the character of the seam are all that are called for at this point.

In Western Pennsylvania it is generally found as a thin seam of excellent quality. It furnishes a good deal of blacksmithing coal for local use. Just upon the border, it is true, there is a small area in which it becomes a cannel coal of large volume (the Darlington Cannel), but after crossing the Ohio line, it resumes its previous character. In the Yellow Creek Valley it is known as the Hammondsville Strip Vein, and it is here a coking coal of unusual excellence, though rather high in ash. Through northern Columbiana the seam is thin and inconspicuous, but generally present. In Stark it again becomes mineable, and is worked at many points, the most important of which are Osnaburg and North Industry. It is here but slightly cementing in character, and one foot of the seam at the first named locality is smith coal. It gains in volume in central Tuscarawas, where it is mined on a large scale. From this point to New Lexington it holds substantially the same character, that of a moderately cementing coal, burning with a bright flame, rather high in sulphur, but low in ash, the latter almost invariably being of a chocolate-red color. The fixed carbon never quite reaches 50 per cent., and the volatile matter never falls below 40 per cent. Throughout this territory, the seam is exceedingly steady and regular in all respects. Its maximum thickness is 5 feet, and its average about 3½ feet. From New Lexington southward and westward, the seam maintains a very different character. It acquires much greater

volume, and becomes a white-ash and typically open-burning coal. The latter characteristics it retains throughout its entire southward extension, but its volume is subject to numerous changes as it is followed toward the Ohio River. There is a large acreage in the Hocking Valley field, where the seam is 6 feet and upwards. It is but 3½ feet along the line of the M. & C. Railroad. It is also thin throughout Jackson county, but in Gallia and Lawrence counties it grows somewhat thicker. It is at least 4′ thick in the Coalton (Ky.) field.

11. The Lower Freeport Coal.

Synonyms.—Coal No. 5, in southern Columbiana county; Coal No. 6*a*, in Stark county and southwestward; Whan seam of New Lisbon; Steubenville Shaft seam; Hamden Furnace coal of Vinton county; Hatcher coal of Lawrence county; Coal No. 8, of the Kentucky series (Crandall).

This is a seam the horizon of which can be followed throughout the entire field, but which becomes workable at comparatively few points. At one locality, Steubenville, it reaches its highest mark, and becomes the basis of one of the best coal fields of the State. It is a coking coal here, and yields a fair article. At New Lisbon it had an excellent name as the Whan seam, but the workable area of the coal was small. It is easy to trace the seam around the northern and western border of the field, for both coal and limestone mark the horizon, and one or both will be found in almost every locality. The seam becomes mineable again in the Hocking Valley, but though 3 feet thick, it is seldom worked, on account of the close proximity of the thicker and better coal of the Middle Kittanning horizon. The Lower Freeport coal ranges from 25 to 65 feet above the Middle Kittanning, and has about the same limits with reference to the Upper Freeport. In Vinton county this seam gets the advantage of the Nelsonville coal, and in the vicinity of Hamden Furnace it is worked in preference to the latter, on account of its greater thickness. In Southern Ohio it is a seam of some local importance, being known as the Hatcher coal in Lawrence county. It is a moderately cementing coal throughout this western field, but is nowhere of the highest quality.

12. The Upper Freeport Coal.

Synonyms.—Coal No. 6, in southern Columbiana county; Coal No. 7, in Stark county and southwestward; Blackband coal of Stark, Tuscarawas, etc.; Big Vein of Salineville; Dell Roy and Sherrodsville coal; Cambridge coal; Alexander coal of Muskingum county; Blue Rock coal of the Muskingum Valley; Bayley's Run and Norris coal of the Hocking Valley; Waterloo coal of Gallia county; Coal No. 9 of the Kentucky series (Crandall).

This seam is the second in importance of the coal seams of the State, ranking next to the Middle Kittanning in the quantity of coal that it holds, and is now producing. It is the center of three well-developed and important fields, viz., Salineville, Sherrodsville, and Cambridge, it makes an important contribution to the fuel supply of other large districts, as central Muskingum, and parts of Perry and Athens counties, and finally it awaits development in what appears to be one of its most promising basins, the Waterloo district of Gallia and Lawrence counties. Of greater value even than the coal of any of these fields is the Blackband ore, which replaces the seam, in whole or in part, in Stark and Tuscarawas counties, and elsewhere.

The Upper Freeport seam is generally a moderately cementing coal, well-jointed, rather soft, without excessive ash, but apt to be high in sulphur. It carries 52 to 55 per cent. of fixed carbon, and always less than 40 per cent. of volatile matter. In its best phases it is highly valued as a steam coal. Its slack cements in the coke-oven, and aside from the presence of sulphur, forms a good coke.

The seam is generally characterized by a considerable number of thin slate partings or binders, in addition to its main and persistent partings. Its normal thickness is 5 to 6 feet, and it is certain that the seam once existed in full and regular development over very large areas, though never in a marginal fringe like the Kittanning coals. Its floor is generally even, but there belongs just above it the coarse and conglomeritic Mahoning sandstone, from which it is separated by a few feet of shale in normal sections, and this is the source of its trouble. The strong currents that brought in the sandstone have carried away the shale, and have cut channels of varying width throughout the body of the coal in all of the fields in which the seam has thus far been developed. These sandstone channels give rise to the "wants" and "horse-

backs," which are the great drawbacks in the working of this seam. The sandstone seldom cuts out the whole body of the coal, but it reduces the seam to 2 feet or less in thickness. The boundaries of the channels are quite abrupt, the coal running down in a few yards from full thickness to unmineable size.

The seam is also disturbed by clay veins to a considerable extent. Despite these drawbacks, it ranks second among Ohio coal seams as to quantity. The Brush Creek coal (Salineville Strip Vein) is commonly worked and classed with the Freeport coals, but as already shown, it does not really belong to the Lower Measures, and it will accordingly be considered elsewhere.

CHAPTER III.

THE COAL SEAMS OF THE LOWER COAL MEASURES OF OHIO—Continued.

MINES OF TRUMBULL, MAHONING, COLUMBIANA, JEFFERSON, PORTAGE, STARK (EXCLUDING THE MASSILLON FIELD), CARROLL, TUSCARAWAS, AND GUERNSEY COUNTIES.

BY EDWARD ORTON.

The general features of the several seams have been roughly sketched in chapter II, and an equally brief description of the development of these seams in their several districts is next in order. This review of the coal fields ot the State is, however, to be regarded as supplementary to the reports already published by the Survey, and not by any means as a full statement of the geology of the districts. Such errors as have been revealed in the sections or details of this earlier work, in the course of subsequent exploration or development, will be pointed out, and special attention will be given to the fields that have been opened since the publication of the previous reports.

COAL MINES OF TRUMBULL COUNTY.

The coal field of Trumbull county is mainly confined to the five southeastern townships, viz., Hubbard, Brookfield, Liberty, Vienna, and Weathersfield. They constitute the most important, and in every way characteristic of the block coal fields of the State. For many years they produced more coal and better, not only than any other equal area in Ohio, but they placed Trumbull far in the lead of the coal-producing counties, but the output is rapidly declining, both relatively and absolutely, and a large part of the territory is already exhausted. Almost every farm has been tested by borings, but so irregular are the deposits of the coal, and so abrupt are their boundaries, that it is not safe to say that there are not workable beds under any

given territory, unless very careful and generally quite expensive investigation has been carried on. The method referred to is unsatisfactory at best. A farm is often drilled over two or three times, by as many different lease-holders, before the coal basins are found. The work of testing is still going forward, but with constantly diminishing force, inasmuch as the chances of any considerable deposits being struck are lessened year by year. Small basins are, however, still being discovered and developed, but a few years at most will terminate the production of coal in Trumbull county on the large scale.

The characteristics of this field have been so fully set forth in previous reports (see especially Newberry's report on Mahoning county, vol. III; and Read's report on Trumbull county, in report of 1870) that it is not necessary to go into full details here. It is, however, to be remarked that quite different grades of coal come into market under the name of Mahoning Valley Block coal. The name does not in all cases stand for fuel of the highest excellence, but it is sometimes made to cover common, or even quite inferior quality. The bulk of the coal fully deserves its excellent name.

But few analyses of the Block coal have been made for the present volume, partly because the character of the coal is so well established, and partly because the field is losing its importance as a source of coal.

The best portions of the seam yield excellent results, as shown in the following analyses, made by Wormley and quoted by Newberry, vol. III, p. 813:

No. 1. Brier Hill coal .... *Wormley.*
No. 2. Veatch's mine .... "

	No. 1.	No. 2.
Moisture	3.60	2.47
Volatile combustible matter..........................	32.58	31.83
Fixed carbon..	62.66	64.25
Ash	1.16	1.45
	100.	100.
Sulphur	0.85	0.56

These figures represent, it must be borne in mind, hand-specimens, and not car-loads. There is no seam of as high average quality as this analysis would indicate in the State, but it is interesting to learn that some portions of the coal that we are now considering, approach so near to perfection as bituminous coal. The percentage of fixed carbon reported was derived from a somewhat different mode of analysis employed by the present Survey.

The Church Hill mines are among the oldest and most extensive of the field. Perhaps no better body of Block coal has been found than is included in this property. When sampled by the methods previously described, the following results of analysis are obtained:

Church Hill Slope, Liberty township .... *Lord.*

Moisture	5.91
Volatile combustible matter	35.01
Fixed carbon	55.70
Ash	3.38
	100.00
Sulphur	0.76

These figures show a very excellent coal, but not, like the last, too bright and good for common use.

A sample of the streak of cannel that sometimes occurs in the middle of the seam gives the following results. (*Lord.*) It will be seen that the percentage of ash is low for a cannel, and that the amount of sulphur is small:

Moisture	2.42
Volatile matter	49.29
Fixed carbon	38.00
Ash	10.29
	100.
Sulphur	0.08

The coal of the Cleveland Shaft, and also of the Chew bank, Brookfield township, ranges somewhat lower in quality, if inference may be safely drawn from single analyses. The results are given below in connection with those of two other mines:

No. 1. Cleveland Shaft, Brookfield township............................ *Lord.*
No. 2. Chew Bank, Brookfield township.. "
No. 3. High Tone Shaft, Liberty township...................................... "
No. 4. California Slope, Hubbard township..................................... "

	1.	2.	3.	4.
Moisture	4.60	4.38	4.69	5.76
Volatile combustible matter	38.36	36.16	35.82	36.72
Fixed carbon	50.42	49.80	48.61	54.91
Ash	6.62	9.66	6.87	2.61
	100.	100.	100.	100.
Sulphur	2.02	3.07	1.01	0.69

The California mine is seen to come up to the first rank as to quality. All of the samples here reported were taken from the bank cars, and represent considerable portions of the mines as now worked. Other portions may of course show somewhat different results.

The Block coal is no longer largely used as an iron-smelting fuel, having been almost entirely displaced by Connellsville coke within the last 10 years throughout the Mahoning Valley. The low rate at which the Pennsylvania coke is now furnished, together with the essential advantages that coke has over raw coal in iron manufacture, has led to this substitution. The Block coal pays a high royalty, and cannot be mined as cheaply as most of the other seams of Ohio and Western Pennsylvania.

In the Cleveland market the Mahoning Valley coal retains its old advantage, commanding, with the other coals of the same horizon, at least 50 cents more per ton than any other bituminous coal that is brought there.

The present condition of the field in Trumbull county can be made out from the following brief notes. In Hubbard township a large part of the possible area of the Block coal has already been mined out, and

no large acreage is left in any continuous body, but exploration is still going on in the small way, and it is occasionally rewarded by the discovery of moderate sized basins that had heretofore escaped notice. Aubrey and Dolling opened in 1882 one of these basins in the northwestern part of the township where it was generally supposed that the coal has been already worked entirely out.

The Applegate Coal Slope (Shenango mine), near the line of Hubbard and Brookfield, and extending into both townships, formerly operated by the Mahoning Coal Company; the Love Coal Bank, operated by Andrews and Hitchcock; the Burnett Coal Slope, operated by the same firm, covered one of the noblest bodies of coal of the entire field, but it is now exhausted.

The Matthews Coal Shaft, operated by Jacobs and Sons, and the California Slope, are the only mines now worked in Hubbard township. The latter is a newly discovered body of small acreage. It will last but a few years at most.

The area of workable coal left in Brookfield township is somewhat larger. A considerable part of the township is below the coal horizon, and most of the sections that are high enough have been pretty thoroughly tested. The Curtis and Boyce Coal Company has made quite thorough work with the coal in the eastern ridge, and on the southern side of the township the Brookfield Tunnel Company has mined out a very large territory. This company has still before it coal enough to furnish 10 or 12 years' supply.

The Cleveland Shaft, operated by the Brookfield Tunnel Coal Company, is near its margin of coal, so far as the territory has been tested. Two other mines, drift banks, viz., the Chew Bank, and the "Brass and Wire" Bank, complete the list of mines now in operation.

A ridge extending northward through the center of the township, is high enough to hold the coal, and has not been thoroughly tested as yet.

All large mining operations have been for some time suspended in Vienna township, but a deposit of considerable value is now undergoing development by Morris, Sampson & Co., at a point about 1 mile southeast of Vienna Center. The coal of this township has never had as good a name as the coal to the south and east, but the new mine, Shadyside, has at present an excellent reputation. The coal is counted of the highest quality.

In Liberty township the coal now known would be exhausted in 3 or 4 years at the present rates of mining. Small areas are added to the available resources of the township occasionally, and in this way the life of the field will be prolonged. The mines at present in operation in this township are as follows:

Kline Coal Co.'s Slope	Tod Iron Co.
Coal Slope, No. 9	Mahoning Coal Co.
Church Hill Slope	Church Hill Coal Co.
Church Hill Shaft	Church Hill Coal Co.
High Tone Coal Shaft	Morris, Sampson & Co.
Garfield Coal Shaft	McCurdy, Margerum & Co.

The last named mine is one of the lately opened mines, and exhibits in striking form the irregularities that belong to the seam in general, and to these narrower swamps in particular.

The coal of Weathersfield township is confined to its southern border, where it constitutes the Mineral Ridge mining field. The Mineral Ridge coal belongs to the general horizon of the Sharon or Block coal, as heretofore determined, but there is in the facts of its occurrence some ground for the earlier opinion of Newberry, by which it was referred to a higher horizon than the Block coal. The coal itself is of a different grade from the Block coal, being much softer and more impure, and of a slightly cementing character. It is often underlain by an excellent Blackband ore, which reaches a maximum thickness of 12 inches. The average is scarcely more than half this. A black slate comes below the ore, and the open-burning Block coal lies still below. The latter is generally thin, but sometimes rises to 2 or 3 feet. Of these several elements, the Blackband ore is the most valuable, and were it not for its presence, a number of the mines would be closed at once, and would probably not be opened again. The section will be better understood by the following diagram:

1.	Mineral Ridge coal, coking	0′ to 4′
2.	Blackband iron ore	0′ to 1′
3.	Coking coal	2″ to 3″
4.	Black slate, called "*Wide awake*"	0′ to 2′
5.	Block coal, open-burning	6″ to 2½′

Some of the larger mines have worked the Block coal in their northerly entries, and the coking coal in the south entries, both seams coming out by the same shaft. The mines of the township are as follows:

Mineral Ridge Coal Slope	Osborn Coal Co.
Norris and Price Coal Shaft	Wm. Williams.
Weathersfield Coal Shaft	D. Morris & Co.
Peacock Coal Shaft	Pierce, Brooks & Co.

The third mine of the list is already drawing pillars. The second and third yield both the Block and the Mineral Ridge or coking coal. The first and fourth produce only the coking coal.

I. COAL MINES OF MAHONING COUNTY.

The Block coal field of Mahoning county is one and the same with the Trumbull county field, and can be described to the best advantage in the present connection.

There are four townships of the county that are known to contain the Sharon seam of workable dimensions, and in considerable area, viz., Youngstown, Austintown, Boardman, and Poland. The first two adjoin Liberty and Weathersfield townships, respectively, and the Youngstown coal agrees in all respects with the Liberty coal, while the Mineral Ridge field of Weathersfield township extends into Austintown, and has an important part of its development there. This last named field will be first taken up.

There are nine mines now in operation in the Sharon seam in Austintown. They all contain the coking or Mineral Ridge coal. Several of them hold good developments of Blackband, and two of them contain the Block coal as well as the coking seam. The mines are as follows :

Austin Mines (Shaft)	Tod, Wells & Co.
Tibbit's Bank (Shaft)	Tod, Wells & Co.
John Henry Mines (Shaft) Thornton Bank	H. & J. Baldwin.
Linn Farm Mines	Cornell & Dalzell.
Pennel Bank (Slope)	New Lisbon Coal Co.
Fool's Errand Bank	Morris & Marshall.
Leadville Mine (Shaft)	Brown, Bonnell & Co.
Jordan Farm Mine	Haroff Coal Co.
Campbell Mine	Marshall & Williams.

Several of these produce excellent furnace coals, as the Pennel, Jordan, and Fool's Errand, and all of them yield a good milling and domestic fuel. As in the townships to the north of them, most of these

mines have seen their best days, and, taken as a whole, the field is verging toward exhaustion.

In Youngstown township we find the Block coal again, agreeing in all respects with the Hubbard coals. The same general statements apply here. The portions of the town in which coal is due have all been sounded. All of the larger bodies have been attacked, and most of them have been worked near to their limits. Small basins are coming to light from time to time, some of them in territory that had already been carefully drilled, as was thought. One of these bodies is now being followed under the northwestern portion of the city of Youngstown.

There are now in operation in the township 5 mines, and a new shaft has just reached the coal in the southern part of the township, not far from Kyle's Corners.

The mines are designated as follows:

Witch Hazel Mine (Shaft)	Witch Hazel Coal Co.
Allen Coal Co.'s Mine (Shaft)	Mahoning Valley Iron Co.
Wellendorf Mine (Shaft)	C. H. & C. W. Andrews.
Foster Mine (Shaft)	Foster Coal Co.
Manning Mine (Shaft)	Manning Coal Co.

The first of these is one of the newly discovered bodies of coal referred to above. There seems good reason to believe that it is an arm of the old Brier Hill basin which was in the main exhausted a number of years ago. The coal was not followed down as low in the early days of mining as it now is, and many of the prolongations of the swamp thus escaped notice. The mine gets its name from the fact that it was located by Chas. Latimer, Esq., Chief Engineer of the N. Y., P. & O. Ry., by means of the forked twig. There is a fair body of coal before it, the probable area being about 20 acres. The quality of the coal is good. It is used to supply the home market of Youngstown, and will without doubt be entirely devoted to this purpose.

The Wellendorf mine is a new mine, with probably but a moderate acreage before it.

The Foster bank is one of the older, and was formerly one of the more important mines of the district, but its days will soon be numbered. Pillars are being drawn, and a few months will close its history. It has yielded a large amount of the best of coal.

The Manning mine is established on a valuable though not very extensive basin.

The Block coal has recently been discovered in Poland and in Boardman townships, and one mine is opened in each. The coal has also been followed in fine development across the line from Youngstown into Coitsville township, in a spur of the Allen mine coal basin.

These nine townships, lying in two counties, embrace the entire block coal field of the Mahoning Valley, so far as its development in Ohio is concerned. They hold a conspicuous and honorable place in the history of coal mining in the State. Possessing, as they originally did, a large area of coal of the highest quality, lying on the margin of the field nearest to the great markets, the business was developed sooner here in the large way than elsewhere in the State, and the whole district has been greatly enriched by it. Royalty has ruled high, a large amount of the coal drawing from 50 to 75 cents per ton. From this source the landowners have received large revenues. Business sagacity and capital have been generously rewarded, and great fortunes have been accumulated from the business directly or indirectly. Nor has labor been unrewarded. Of the miners that have been temperate and frugal, a large number live under their own roofs, and have secured a reasonable competence. Some of their villages rate highest for intelligence and order among the mining communities of the State.

The mining of the block coal calls for and cultivates skill. Only well-trained men can make proper headway in attacking a seam of this character. It is mined mainly without explosives, and under the best of the more recent practice is made to yield at the rate of 5,000 tons for an average of 4 feet to the acre. It makes but little slack when properly handled, 2,100 lbs. of unscreened coal being commonly counted one ton of clean coal. The weight of the screenings in the California mine, as shown by a "Billy Fairplay," ranges from 100 to 300 lbs., the screens being $1\frac{1}{4}''$ between bars. The same test, when applied to the Mineral Ridge coal, gave 1144 lbs. of slack and nut coal to one ton of clean coal. In this region, therefore, the screenings take an average of $\frac{1}{3}$ of the coal that comes from the shaft. The Blackband ore is the element that maintains this latter field, both of the coals being too thin for profitable mining independently. The heavy black slate, called "wide-awake," lying between the Block coal and the Blackband, complicates the mining.

Where it occurs, the whole seam is "shot out of the solid," and thus the upper coal, which is weak at best, is much broken.

The price of mining is graduated to the thickness of the coal in the room, sometimes by an accepted scale, and sometimes by special agreement that reaches substantially the same result. Counting 65 cents as the price of mining 4′ coal, an addition of 5 cents per ton is made for every 3 inches below 4′, the maximum of $1.00 being rarely reached.

The special adaptation of the Block coal to iron manufacture was an important factor in the earlier development of the field. For a long time it has been the fashion to deplore the rapidly hastening exhaustion of the supply, and to deprecate the use of this excellent fuel for more common purposes, but events are proving that the coal went at the right time, and in a way most serviceable to all the interests concerned. What is left of it is suffering severely from competition with the various newer fields of Ohio and Pennsylvania, and with all the advantages that its high quality affords, it is barely able to maintain itself in market. The element of royalty alone counts heavily against it, the excess in this particular above the coals that it meets being often 50 cents per ton, and sometimes more.

As to the southward extension of this valuable seam, little is to be said. Not a single clear occurrence of it has been reported in Eastern Ohio south of the points named, except that a recent drilling shows 4½ feet of coal at a depth of 307 feet near the boundary of Austintown and Canfield townships.

The coals struck at Leetonia and New Lisbon, in the valley of Bull Creek, and in the Ohio Valley, near Smith's Ferry, belong, without exception, to the Mercer horizon, and have been referred to the Sharon level only through the dislocation of the series that has already been pointed out. When the Lower Kittanning coal was counted the Lower Mercer, the true Lower Mercer would not be far out of place for the Sharon seam; or, to use the numeral designations, when No. 5 was counted No. 3, then the true No. 3 would answer fairly well for No. 1.

Aside from the very valuable deposits already described, Mahoning county has no large supplies of coal for the general market, but its whole surface is occupied by the Lower Coal Measures, and there are

mines opened in every township for neighborhood use. In Green township there is, however, a fair development of both the Lower Kittanning and the Clarion coals, both of which have been mined on quite a large scale for shipment on the Niles and New Lisbon Railroad.

The local supplies of coal already referred to, that are obtained from farmers' banks, are by no means to be overlooked in making out the coal resources of a county. The seams may be thin, or may lack adaptation in other ways for mining on the large scale, but the fuel of entire communities, counting in the villages which they include, is often obtained from country banks in which not more than two or three miners are ever employed at one time, and for only a few months in the year.

The coal supply of Mahoning county is mainly of this character, as can be learned from Newberry's report, in vol. III. To the statements made in the above named report, a few additional facts will be here given, pertaining to the coal seams of Canfield and Green townships.

Three seams are worked in Canfield township, but all are thin. They are the Mercer coals, Lower and Upper, and the Clarion coal, Upper, as has been already shown on page 30.

The Lower Mercer or Blue Limestone coal (Coal No. 3 of Newberry) is generally known in this region as Coal No. 2, it being the first mineable seam above the Sharon seam. The interval between these two coals is counted about 150 feet, but it is often considerably less, and seldom, if ever, more. The only mine in the State in the Lower Mercer seam which ships coal by railroad, is found in Canfield township. On the Jas. Turner farm, a shaft has been sunk to the coal by Wick and McDowell, and the mine has been in operation for a number of years, but the output has never been large. The seam is 30 inches thick, and like the Lower Mercer coal generally, it has more or less bone and slate distributed through it. The coal at this point lies 15 to 20 feet below the limestone. Both limestone and ore have been largely worked here, and all combine to make the exhibition of the Lower Mercer horizon on North Run of Meander Creek, one of the most full and satisfactory to be found in the State. The section on the Beardsley and Turner farms is as follows:

	Ft.	In.
Coarse sandstone—Containing coal plants.		
Shale and clay	2	
Block ore—Formerly mined by stripping	0	6
Lower Mercer limestone—Worked for furnaces	2	6
Shales—Dark	0–20	
Lower Mercer coal	2	6
Fire-clay	2	
Shales—Blue-black, crowded with ore nodules, calcareous, and containing sulphide of zinc	15	
Sandstone—Massillon.		

The same seam has been worked to a small extent on the Fink farm, and also on the D. Heinzelman farm.

The Upper Mercer coal is of much more importance in the township than the seam already described. It occurs about 35 feet above the Lower Mercer limestone, and is generally known as Coal No. 3. In Newberry's scale it is No. 3*a*. The Upper Mercer limestone frequently accompanies the coal, but is by no means as steady as the latter. It lies in disconnected blocks, buried in clay, upon the outcrop, and is a troublesome element in mining the coal. On the John Kirkpatrick farm the section of limestone and coal are as follows (T. J. Wise's bank):

	Ft.	In.
Upper Mercer limestone—Blue and fossiliferous	0	4
Black shale	4	0
Upper Mercer coal	2	
Fire-clay	-	–

The coal is said to become 6 inches thicker in some parts of the mine. It is worked at this point steadily, two or three miners being employed. The coal is of fair quality, and commands a ready sale at the bank. It is mined for the same price that is paid in the Block coal mines to the northward. It is opened on 6 or 7 farms in the township, but the description already given will apply to all.

The third and last of the coal seams of the township is the well-known Canfield cannel. It is called No. 4 in the township series, and Newberry has adopted the same designation, but it has already been shown that it is not the seam called No. 4 in Stark and Tuscarawas counties. That coal underlies the Gray or Putnam Hill limestone, the place of which is 30 or 40 feet below the Canfield cannel. The latter seam is 85 feet above the Upper Mercer coal, and 120 feet above the Lower Mercer limestone, and two seams of coal are due in the interval,

viz., the Tionesta coal and the Brookville coal, which is Newberry's No. 4, to the westward.

Neither of them appears in the Canfield sections, and this fact has led to erroneous views in regard to the general series. It has already been shown that the Canfield cannel is the Upper Clarion coal, the place of which is directly below the Ferriferous or Lowellville limestone. All of the facts match to this interpretation.

The duplication of the seam has already been described (see page 32). It begins in the southern part of Canfield township, being well seen on John Ewing's farm, where the interval that separates the two deposits is 8 feet of clay, but in the adjoining portions of Green township there are numerous examples of it. Mr. T. J. Wise, of Canfield, gives me the record of several borings on the farm of James M. Pettit, Green township, near the line of the railroad. One record is as follows:

	Ft.	In.
Sandstone	41	
Chip slate—Black	2	6
Dark-gray slate	10	
Black slate	4	6
Coal—Canfield cannel seam	3	5
Fire-clay	—	4
Coal—Sulphurous and impure	3	9
Fire-clay	2	

This lower coal was found to maintain the thickness here given for about an acre in the center of a basin. It has never proved to be of marketable value. This may be the Lower Clarion coal, which is sometimes separated from the limestone by as much as 20 feet in the Pennsylvania series, but it is more likely a local duplication. There is no possible warrant for counting it the Upper Mercer coal, as has sometimes been done. The latter seam would need to be moved 80 feet out of its true horizon to take this place, but it holds its own place in the series, as is shown in the Leetonia borings, a few miles to the southward (see page 35).

The seam changes its character in the southern part of the township and below, becoming a bituminous coal, except for a sheet 4 to 6 inches in thickness at the top of the bed, which is an impure cannel.

The only considerable mine in the Upper Clarion coal in the county, and one of the few in Eastern Ohio, is the one that is located at Cook's Crossing in Green township. The seam is here less than 3 feet thick

in its bituminous portion, but the cannel block is also taken down in the entries. The coal lies on an uneven floor, the hills rising fully 20 feet above the swamps. The quality is not high, and mining has not been carried on with any great profit.

The seam is found here 29 feet below the grade of the railroad, and it does not rise to day again until the westward sweep of the valley of the Middle Fork brings it just above the water between Robbins's and New Lisbon. Another seam is due above it throughout a considerable part of the territory already traversed, viz., the Lower Kittanning coal. Its place is 30 to 50 feet above the Canfield cannel seam. It is not known on this line north of Green Station, where it is found 15 feet above the railroad. This seam has hitherto been mistaken for the Canfield seam, which is always in its own place below the Kittanning coal. In other words, we have two seams of mineable coal south of Green Station, where, according to the system of naming the coals above referred to, only one is due. When the Kittanning coal receives the designation of No. 4, the Clarion coal has been styled No. 3, but why it should not have been called No. 3*a* is not apparent. The valuable section found at Walters's mine, on the south line of Green township, has already been given (see page 33). At this point both the Lower Kittanning and Clarion coals have been worked together.

The coal of the west side of Beaver township is certainly the Upper Clarion seam. The registers of two borings, cited by Newberry in vol. III, pp. 808–9, prove very interesting. They are as follows:

Register of Well on Samuel Bare's Farm.

		Ft.	In.
1.	Surface deposits	32	
2.	Sand rock	34	
3.	Black shale	5	
4.	Cannel coal	4	6
5.	Black shale	1	6
6.	Fire-clay	14	
7.	Fire-clay rock	17	
8.	Gray shale with thin coal	8	6
9.	Gray shelly rock	1	4
10.	Gray shale	17	
11.	Dark shale with thin coal	3	
12.	"Very hard rock"	1	6
13.	Brown shale	7	
14.	Fire-clay	4	6

15.	Gray shale	8	
16.	Light sand rock	9	6
17.	Gray shale	5	
18.	Black shale	1	
19.	Flinty rock	1	8
20.	Coal	1	6
21.	Sand rock	3	
22.	Bottom rock	—	

Register of Well on Noah Messerly's Farm.

		Ft.	In.
1.	Surface deposits	30	
2.	Sand rock	48	
3.	Black shale	8	
4.	Cannel coal	5	6
5.	Black shale	1	
6.	Coal, very sulphurous	3	
7.	Dark-gray shale	8	
8.	Coal	2	
9.	Black shale	5	
10.	Sand rock	10	
11.	Gray shaly rock	15	
12.	Gray shale	4	6
13.	Black shale	4	6
14.	Coal and shale	1	
15.	Fire-clay	3	
16.	Fire-clay rock	10	
17.	Gray shale	6	
18.	Brown sand rock	8	
19.	Fire-clay	1	
20.	Gray sand rock	21	
21.	Black flinty rock	1	
22.	Black shale	1	
23.	Bottom rock	—	

In the light of the facts already given, these registers are perfectly clear and unambiguous. In the first, the flinty rock, No. 19, is the Lower Mercer limestone, and the coal below it is, of course, the Lower Mercer coal. No. 12, the "very hard rock," is the Upper Mercer limestone, and Nos. 3, 4, 5 and 6 mark the horizon of the Clarion Upper coal.

In the second record, Nos. 21 and 22 indicate the Lower Mercer horizon, Nos. 13 and 14 the Upper Mercer, and Nos. 4, 5 and 6 show the Clarion coals in the same order in which the seam is found to the westward, No. 8 may stand for the Clarion Lower coal.

The intervals will be seen to match fairly well with the facts already recorded. They are as follows:

	1.	2.
Clarion Upper coal	102	96
Mercer Upper horizon	40	41
Mercer Lower limestone	0	0

The horizon of the Block coal lies 150 feet below the "bottom rock," so called. There seems but little reason to expect workable deposits of the lower seam so far within the field as this point, but no test of its presence has yet been made.

The error of counting the Canfield cannel seam and the Leetonia coal as one and the same has extended to adjoining townships, and especially to Beaver and Springfield. The seam called No. 4, in Springfield, is the Lower Kittanning or Leetonia seam, while both coals are so named in Beaver as they have been shown to be in Green.

It is of interest to note that the largest and most important field of the Clarion coal in Ohio is found in this immediate region. Beginning at Canfield, it extends as far southward as New Lisbon. While the quality is inferior, it still makes an important contribution to the fuel of the State. The time will come when the nicer shades of quality will no longer be available, or when at least cheaper grades of coal will be sought for various uses. This seam may await a full development when these conditions are reached.

II. COAL MINES OF COLUMBIANA COUNTY.

According to the census tables of 1880, this county held the 4th rank among the coal-producing counties of the State, its output for the census year being 541,466 tons, and 18 large and 16 small mines being reported. The general geology of the county has been quite fully treated in volume III, and the details of its more important coal fields, which are there given, can be adopted in the present report, subject to the same rectification of geological order that has already been applied in the present report.

The coal seams of the county belong mainly to the Lower Coal Measures, and are as follows:

Brush Creek coal.—Salineville Strip Vein, No. 7.
(40 to 50 feet interval.) Mahoning sandstone, lower division.

Upper Freeport coal.—Big Vein of Salineville, Teegarden coal, Rochester coal, State Line coal, Coal No. 6.
(40 to 65 feet interval.)

Lower Freeport coal.—Roger seam, Whan coal, Coal No. 5.
(15 to 65 feet interval.)

Middle Kittanning coal.—Hammondsville Strip Vein, Block Vein of Ohio Valley, Dry Run Vein, Darlington cannel, sometimes No. 5, sometimes No. 4, No. 6 of Tuscarawas county.
(18 to 30 feet interval.)

Lower Kittanning coal.—Leetonia seam, Clay Vein, Potter's Vein, and Sulphur Vein of Ohio Valley, Creek Vein of Yellow Creek Valley, No. 4 at Leetonia, etc., No. 3 in Ohio Valley, No. 5 in Tuscarawas county.
(40 feet interval.)

Upper Clarion coal.—Canfield cannel, Creek Vein at New Lisbon, No. 3 at Leetonia and New Lisbon, No. 4 in Mahoning county.

These six seams constitute the sole reliance of the county in the way of coal. There are several thin and uncertain seams in the Barren Measures above the Salineville Strip Vein, the outcrops of which are occasionally seen, but none of them is known to be mined, even in a single instance. The Mercer horizon comes to view in at least one uplift of moderate extent in the county which has its highest elevation at Fredericktown, in the valley of the Little Beaver, and which may be named, as White suggests, the Fredericktown anticlinal. Another arch, or possibly a continuation of the same one, which has its summit between East Liverpool and Wellsville, probably brings up the Mercer group, but in neither case is the coal thus shown of any importance. The heavy bed of fire-clay that is worked at Walker's Station, 125 feet below the Lower Kittanning coal, is very likely the clay of the Tionesta coal. At all events, it is not very far above the Mercer horizon.

The lowest of the coal seams named above, viz., the Clarion coal, is mainly confined in its outcrops to the valleys of the Little Beaver

and the Middle Fork. Its chief economic development is in the latter valley. It has long been mined at New Lisbon, and for several miles above the town, where it is known as the Creek Vein. It is Newberry's No. 3 in this region. It is reached in the Salem shaft at a distance of 44 feet below the Lower Kittanning coal, and was mined here for a number of years. It has also been mined at Walters's Shaft at Washingtonville, and it is struck of good thickness in all of the drill-holes at Leetonia. Its place is well marked in the main valley, and also in the East Fork, but the coal has no value here.

Practically, throughout most of the county, the Lower Kittanning or Clay Vein coal constitutes the base of the coal series. That the Clay Vein coal of the Ohio Valley is the Lower Kittanning of the Pennsylvania series does not admit of question. It is a demonstrated geological fact.

Many deep borings have been made for oil and gas in the Ohio Valley, but very little coal has been reported below this seam. It is the second in importance among the coal seams of the county, ranking below the Upper Freeport coal only. In quality it shows a wide range, furnishing fuel of unusual purity in the northern portion of the county, but becoming very sulphurous in the southern part.

The Middle Kittanning coal is less valuable, relatively and absolutely, in Columbiana county than in any other county of the State in which it occupies as wide an area. It is less than 1 foot in thickness wherever seen through the northern and central portions of the county, and is nowhere opened here. In the Ohio Valley it is known as the Block Vein, and as the Hammondsville Strip Vein, and about East Liverpool as the Dry Run coal. Its quality is here so good that it is extensively worked in small mines, although its thickness ranges between 20 and 32 inches, rarely reaching the latter figure.

The Lower Freeport seam makes an important contribution to the coal supply of the county. As usual, however, it is unsteady and uncertain. A very valuable basin of it was found near New Lisbon a number of years ago, which was known as the Whan coal. This basin is now exhausted. The seam is frequently worked in the southern part of the county in a small way. It is here known as the Roger Vein.

The Upper Freeport coal is by far the most important seam of the series. Its horizon is reached in every township of the county, and the coal is mined in all but three of the townships. The two great mining

centers of the county, Salineville and Palestine, depend upon this seam as the basis of their operations, though other seams are also worked.

The above named seam completes the Lower Coal Measures, but this division might well have been enlarged to take in the next seam above, viz., the Brush Creek coal of Pennsylvania, or the Salineville Strip Vein, a seam which, though never attaining great thickness, is so excellent in quality and so steady in character that it has been worked in a small way in many counties of Ohio, but in no other section of the State does it attain the importance that it possesses in Columbiana and Jefferson counties.

The frame-work of the series has now been given, and a few statements will be added as to the special fields. We can advance with most profit along the line of the Niles and New Lisbon Railroad, which we have already followed through Mahoning county.

The sections at Leetonia and New Lisbon have already been given (see Figs. XI and XII), and they fairly represent the geology of the ten northern townships of the county. In the northwestern corner of the county, however, the deposits of the glacial drift cover the surface, so as to obscure the bedded rocks to a considerable degree. The section at Linton in the Yellow Creek Valley is shown in Fig. XIII, and this applies to all the lower portion of the county, except that 300 to 500 feet of the Barren Measures come in above the summit of the Lower Coal Measures in that district.

The Leetonia Field.

The Leetonia coal field is an important one. It covers, not the heaviest, but, all things considered, the most valuable deposit of the Lower Kittanning coal in the State. The boundaries of the field, so far as it has been fully tested, are not wide. On the northward, as we have already seen, it does not extend beyond Green Station, being cut out beyond that, apparently, by the descent of the Lower Freeport sandstone. To the west it is found in fair volume and quality, as far at least as Salem, within the limits of which a shaft has been sunk to the coal and below. It thins out rapidly to the southward, and is scarcely found of workable volume again until it is followed beyond New Lisbon. To the eastward it has not been fully proved, but there are several facts that point toward a valuable extension of the field in that direction,

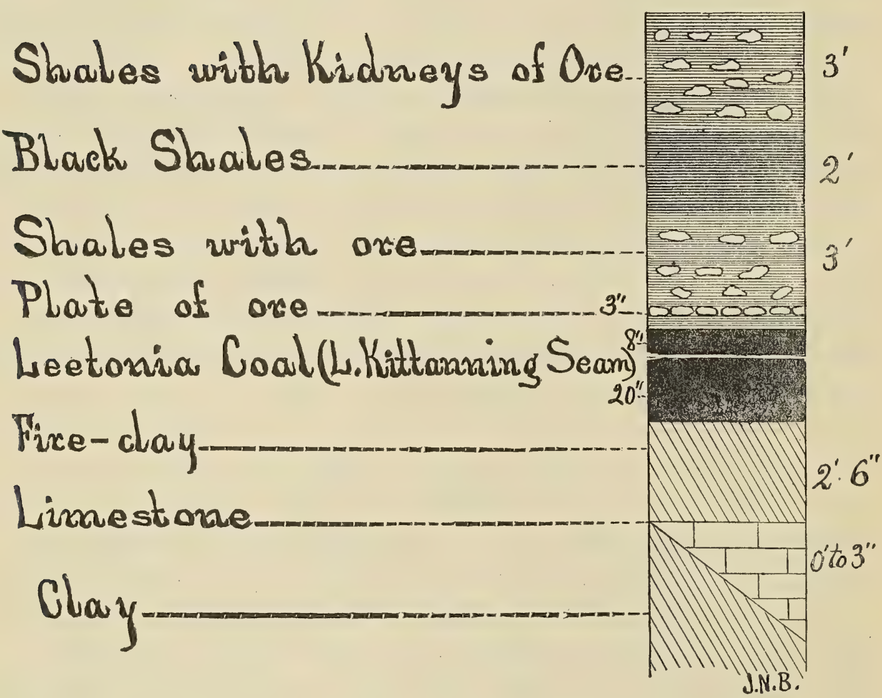
the coal growing somewhat thicker, and holding its good character for several miles beyond Leetonia.

The section that includes the Leetonia coal is as follows:

FIGURE XXV

SECTION AT LEETONIA ENCLOSING COAL.

Vertical Scale 5 ft. = 1 inch.



		Ft.	In.
1.	Shales, with numerous kidneys of ore	3	
2.	Black slate	2	
3.	Shales, with kidneys and plates of ore	3	
4.	Leetonia (Lower Kittanning) coal.......2 ft. 4 in. to	2	6
5.	Fire-clay	2	6
6.	Limestone—Non-fossiliferous	0–3	
	Clay.		

The shales above No. 1 of the section are abundantly charged with kidneys of iron-ore. The horizon is almost everywhere ore-bearing. This is the most important single source of the ore that is found in the alluvial deposits of the Middle Fork Valley, and which has been mined on a large scale at and near New Lisbon. The Black slate, No. 2, is an almost constant accompaniment of the coal, sometimes rising to 15 or 20 feet in thickness. No. 3 often furnishes continuous seams or plates of ore, which sometimes become a Blackband ore.

The coal is found in two benches, as indicated in the figure, the lower of which is much the purer. The upper bench often becomes slaty and cannel-like, and must then be rejected. The bottom coal, which is also called the smith coal, is a cementing coal of pronounced character, but the upper bench never has this quality. The coke manufactured from the Leetonia seam holds a high place among Ohio cokes, both as to strength and purity. It has long been manufactured in the large way for the use of the furnaces of the Cherry Valley and the Grafton Iron Works that are located here, only the lower bench being mined for this purpose. The bottom coal is also an exceptionally good fuel for rolling-mill use. It burns with a bright blaze, and gives out its heat quickly. No coal in the State is more highly approved as a milling coal.

For domestic use the seam is not quite as well adapted, but as a steam coal it again takes high rank. The top coal is mined with the bottom for railroad use, the character of the product being notably improved thereby. The principal drawback to the seam for domestic fuel is the fact that it mines small. The coal is rather weak in texture, and, though mined without powder, nearly one-third that comes from the bank-cars passes through a screen, the bars of which are $\frac{7}{8}$ of an inch apart. Where only the bottom bench is worked, a still larger proportion is small coal. Where coke-ovens are connected with the mine, these facts constitute no drawback, but they bear directly upon the shipping banks.

The oldest and largest mines at this point are the two connected with the Cherry Valley Iron Works, one of them being located at the furnace, and the other at Washingtonville. These mines have been managed with great skill and success, and furnish a lesson of great value to the State in showing that low coals can, even under present

conditions, be successfully taken out, if the work is wisely ordered, and particularly if the character of the coal is high enough.

The following analyses of the Leetonia coal and coke bear out all that has been claimed for them, and more. Both mines belong to the Cherry Valley Iron Works:

1. Analysis of coal from Leetonia mine ....*Lord.*
2. Analysis of coal from Washingtonville mine .... "
3. Analysis of coke from No. 1 .... "
4. Analysis of coke from No. 2.. "

	1.	2.
Moisture	3.60	4.37
Volatile matter	37.86	35.50
Fixed carbon	56.14	57.91
Ash	2.40	2.22
	100.	100.
Sulphur	0.82	0.69

	3.	4.
Ash	8.47	5.86
Sulphur	1.08	0.61

These are remarkable results, and they place this little seam almost at the head of Ohio coals as far as quality is concerned.

Walters's mine at Washingtonville is now a railroad bank, furnishing 300 tons daily for use in locomotives. The coal is counted second only to the Pittsburgh coal for this use, where it has been tried. The seam is here a trifle stronger than at Leetonia, the measure rising to 32 inches, all told. The increase is in the top bench, the quality of which improves as it thickens. The present price of mining is 95 cents per ton, for the coal that passes over a $\frac{7}{8}$-inch screen. The present price for mining the coal when weighed as it comes from the bank-cars is 63 cents. These facts are of interest, inasmuch as the Leetonia coal is the thinnest coal now worked in the large way in Ohio.

About 400 acres of this seam at this thickness have already been worked out in the Leetonia and adjacent Washingtonville mines.

The Leetonia field embraces also the Clarion coal, which exists in good thickness and within easy reach throughout the whole neighborhood. It is the seam known as the Canfield Cannel coal at the northward, and is one of the coals designated as No. 4 by Newberry.

It is reached by a shaft at Walters's mine at Washingtonville at a distance of 44 feet below the coal last described. It was worked here for some time, but though the volume of the seam is large enough, its quality is generally poor. It is shown in every record of the borings made at Leetonia. It is what is called a "dirty" coal, many slate-bands interrupting its continuity, and it also carries pyrite or "sulphur" in large amount, both diffused and concentrated. It is fairly high in fixed carbon, and in heating power is not inferior to the Leetonia seam, but it has a tendency to run on the grate-bars, and makes "clinker" in large amount. Its floor is uneven, but there are not many "wants" in the coal. The seam climbs the hills of the mine in fair volume, being unlike the Block coal seam in this respect. It is very regular throughout this district, which holds almost the only valuable deposit of this seam in the State.

It is mined at Franklin Square or Armstrong's Station, just south of Leetonia, where it is reached by a short shaft, and also at Maurer's mine, 3 miles north of New Lisbon. The characteristics already given apply to all the mines that are now worked. The geological relations of the seam and the elements with which it is directly associated, have been already fully described. The fossiliferous black shale, that so often replaces the Ferriferous limestone, is well shown here as the cover of the coal. The Leetonia seam has lately been opened at this point, a little thinner than at Leetonia.

As previously stated, the Leetonia coal extends at least as far west as Salem, and has been reached by a shaft within the limits of the town. The record of the shaft is a valuable one, and is repeated here from vol. III, page 125:

	Ft.	In.
1. Earth	9	7
2. Red shaly sandstone	9	0
3. Black shale	1	6
4. Slaty coal	0	6
5. Sandstone	39	0
6. Black shale	20	6
7. Gray shale	21	4
8. Leetonia seam	2	6

		Ft.	In.
9.	Fire-clay	11	9
10.	Gray sandstone	1	5
11.	Clay shale	3	6
12.	Gray sandy shale	20	8
13.	Blue calcareous coal with shells	2	0
14.	Coal with 2-inch parting, 1 foot from bottom	5	0
15.	Fire clay	1	9
16.	White sandstone	6	3
17.	Clay shale	7	8
18.	Black shale	1	0
19.	Coal	1	6
20.	Fire-clay	20	3
21.	Iron ore	1	0
22.	Shale	13	3
23.	Dark sandrock	6	7

The elements that deserve special notice here are the following, viz.:

Nos. 3 and 4. Lower Freeport coal.
No. 5. Lower Freeport sandstone.
No. 6. Covering horizon of Middle Kittanning coal.
No. 8. Leetonia or Lower Kittanning coal.
No. 9. Kittanning clay.
No. 13. Ferriferous limestone horizon.
No. 14. Clarion coal, doubled as elsewhere.
No. 19. Lower Clarion coal ?

The analyses of the two benches of the Leetonia coal, No. 8, and also of the Clarion or Canfield coal, No. 14, are given in Newberry's report in vol. III, and may profitably be repeated here. They are as follows:

1. Lower Bench, Leetonia seam in Salem shaft.
2. Upper Bench, Leetonia seam in Salem shaft.
3. Clarion coal (Canfield Cannel seam), Salem shaft.

	1.	2.	3.
Moisture	3.00	2.60	2.20
Volatile combustible matter	31.50	36.40	36.00
Fixed carbon	62.35	53.30	57.40
Ash	3.15	7.70	4.4C
	100.	100.	100.
Sulphur	1.40	2.28	4.38

The analysis of the Leetonia coal and coke has been already given, and can be compared with these results.

The Clarion coal, as shown in No. 3, appears to unusual advantage. Aside from the high percentage of sulphur, it would seem to be a first class coal, but the analysis is too favorable, being probably made from selected samples.

The line of facts brought to light by the several well records at Leetonia will be borne in mind in this connection (see pages 35 and 36).

The Leetonia field includes the New Albany coal of Green township, Mahoning county, where the seam reaches its best development. It has long been worked here for the supply of the adjoining county, and especially for the town of Salem.

In the southern portion of Salem township, and also in Centre township, we find the Freeport coals and also the Brush Creek coal coming into the section. The Upper Freeport coal gave a flattering promise on the Shelton and Arter farms, and was opened there a number of years ago with great expectations. The coal was 7 feet thick on the outcrop, but it soon ran down to 3 feet, and was left at $2\frac{1}{2}$ feet a short distance under the hill. It averages about 4 feet in the neighborhood, and is still worked, though not in large mines. The Brush Creek coal on the Arter farm is found 38 feet above the Upper Freeport, but a short distance below a seam is opened only 12 to 15 feet above the Big Vein. Whether this is the Brush Creek coal or one of the irregular beds that sometimes occur at the Upper Freeport horizon, cannot be decided here. The series shown in this immediate vicinity is as follows:

Brush Creek coal ....Newberry's No. 7.
38 feet.
Upper Freeport coal—*Big Vein* ....Newberry's No. 6.
32 feet.
Lower Freeport coal—*Whan seam*..................................Newberry's No. 5.
88 feet.
Lower Kittanning coal—*Leetonia seam*.........................Newberry's No. 4.
30 feet.
Upper Clarion coal—*Creek Vein*.... ....Newberry's No. 3.

The other elements that are due, and especially the limestones, all come in their places with regularity. The Upper Freeport or White limestone, as it is here designated, is a constant and conspicuous stratum. The Lower Freeport limestone is mined on a large scale in this imme-

diate vicinity as a cement rock. Finally, the Ferriferous limestone is found covering the Creek Vein coal in numerous sections. It is blue in color, not more than 3 feet thick at any point, and charged with characteristic fossils.

Of the five seams named above, the second and the last furnish all the coal that comes out on the railroad between Leetonia and New Lisbon. Three shipping mines are opened on the Big Vein, and one on the Upper Clarion seam. The former are named the Wolf Run, Shelton and Maple Hill mines; the latter is known as the Rock Hill mine, and belongs to the Niles Mining Company. The coal of the Big Vein is of the usual character, a strong and serviceable fuel, with rather a high percentage of sulphur. Thin seams of shale occur at irregular intervals, which increase the ash of the coal at times beyond the usual limits.

The coal of the Rock Hill mine (Upper Clarion or Canfield Cannel) is highly cementing, and ranges in thickness from 2 ft. 6. in. to 3 ft. 10 in. It is without regular partings. It is a "hilly" seam, the floor being very uneven. Above the coal is a "draw-slate," 8 to 12 in. thick, black and highly fossiliferous, and charged with cone-in-cone. This slate represents the Ferriferous limestone in numberless sections throughout the region. The coal contains large balls of pyrites, of the kind known as "black sulphur." These masses are sometimes 12 or 14 inches in thickness, and weigh many hundred pounds The fire-clay beneath the coal is of excellent quality, and has long been worked in this vicinity. It ranges from 1 ft. 6 in. to 4 ft. in thickness. Under the clay the seam of coal that has been shown in so many other instances occurs.

At one point in the mine, in digging a "sump," this lower seam was found 20 inches thick. The coal, however, is poor, and it is never taken out.

The mine is entered by a slope, the coal lying at and below the level of low water in the creek, and under a heavy hill. On account of its situation and character it accumulates fire-damp, and one of the most destructive explosions of Ohio mines occurred in it a few years ago. Since that time it has been under more careful management in this regard.

The section that includes the coal is an interesting one. It is shown in Fig. XXVI. It requires no comment.

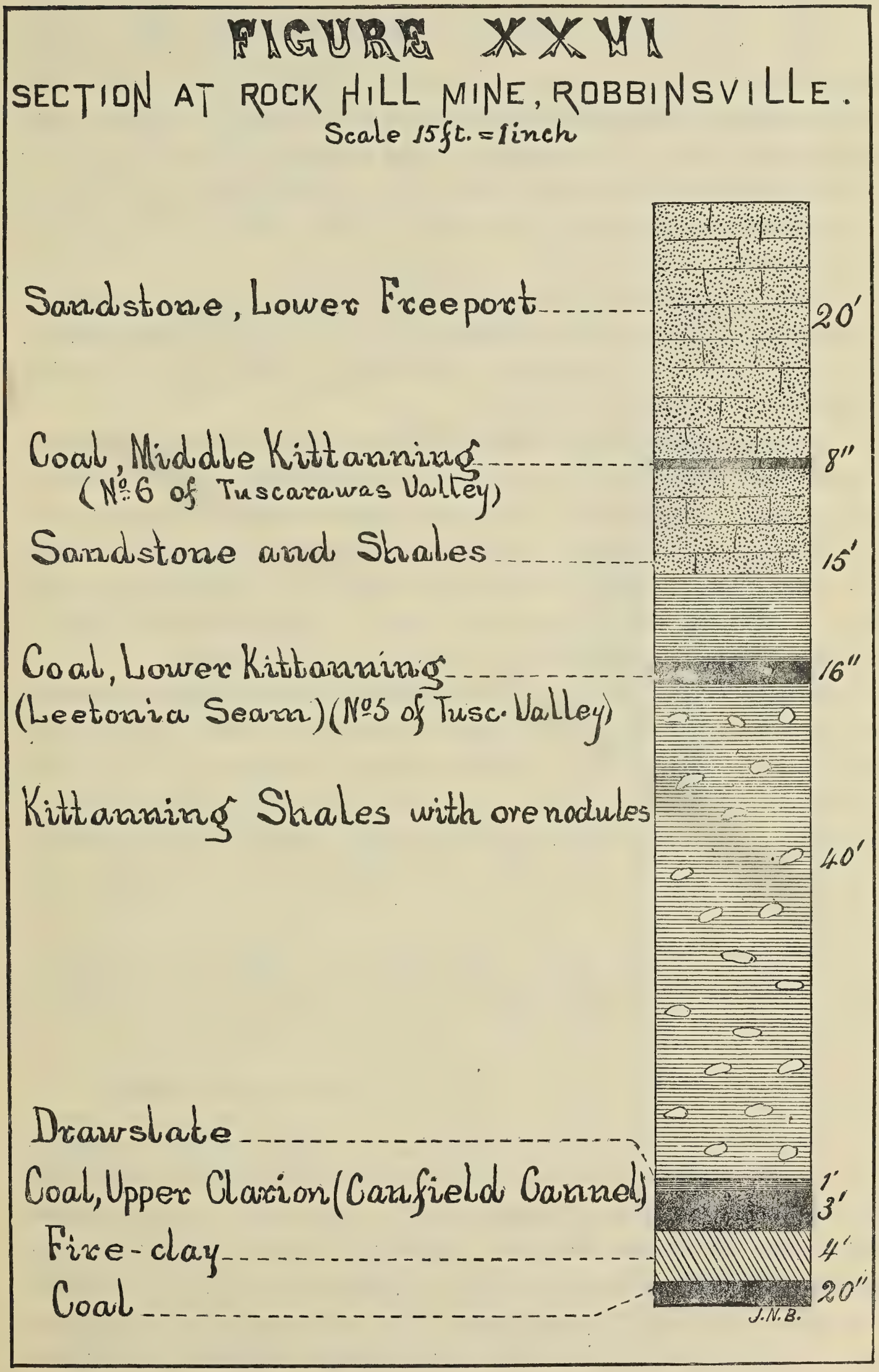


FIGURE XXVI
SECTION AT ROCK HILL MINE, ROBBINSVILLE.
Scale 15ft. = 1 inch
Sandstone, Lower Freeport
20′
Coal, Middle Kittanning
(No. 6 of Tuscarawas Valley)
8″
Sandstone and Shales
15′
Coal, Lower Kittanning
(Leetonia Seam) (No. 5 of Tusc. Valley)
16″
Kittanning Shales with ore nodules
40′
Drawslate
1′
Coal, Upper Clarion (Canfield Cannel)
3′
Fire-clay
4′
Coal
20″
J.N.B.

The Lower Freeport limestone is worked on quite a large scale a mile below the point last named as a cement rock. It lies 68 feet above the Lower Kittanning coal. The Lower Freeport coal is but a few inches thick at this point, being cut out by the Upper Freeport sandstone, which rests directly on it. It is 7 feet above the limestone, or 75 feet above the Kittanning coal. The sandstone has a thickness of 18 feet where it is shown. A fire-clay of some promise often comes in at this horizon.

From New Lisbon perfect connections can be made, by means of the Freeport coals especially, with all the other sections of the county. The whole series can in fact be followed along the sides of the deep valleys that traverse the county.

Two miles below New Lisbon the Lower Freeport seam was mined a number of years since under the name of the Whan coal. The coal had an excellent reputation, and was of good thickness, ranging from 4 to 5 feet, but the field proved to be very limited, and it has been worked out. The main reliance of Elk Run, Middleton, and St. Clair townships is the Upper Freeport coal, which is opened in many farmers' banks. It holds its usual character throughout the region.

From the main valley of Little Beaver we can follow the section with which we have been engaged, in whole or in part, in three directions, viz., southward into the Ohio Valley, and through this to the Yellow Creek Mining District, of which Salineville may be taken as the center, westward by the West Fork Valley to Millport and Rochester, and northward by the East Fork to the East Palestine and State Line coal fields.

The first and the last of these localities constitute the most important mining centers of the county, and are among the most important of this section of the State. They will be briefly described.

The East Palestine and State Line Coal Field.

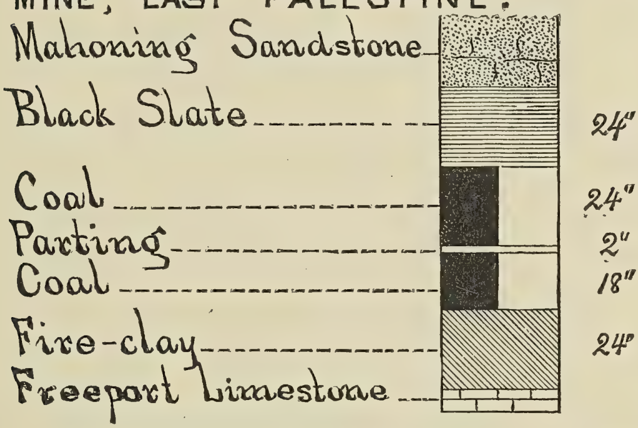
The Ohio portion of these mines is included in Unity township. Two seams contribute to the production, viz., the Upper Freeport and the Brush Creek seams, Newberry's No. 6 and No. 7 for this region. The former is by far the more important, being at present the only seam worked. Two mines are now running at this point, viz., the State Line mine, and the Prospect mine. The whole output of the former goes to the Pittsburgh, Fort Wayne and Chicago Railroad. It employs

350 men, and sends out an average of more than 650 tons daily. The railroad company is about erecting dumps for the supply of their engines at this point.

The seam has a general thickness of 3 ft. 8 in. in this field. The thinnest coal found in the State Line mine is 3 ft. 4 in., and the thickest 4 ft. 10 in. The quality proves best where the coal is thickest. The structure of the seam is as follows:

FIGURE XXVII.

STRUCTURE OF UPPER FREEPORT COAL (No. 6 OF NEWBERRY) AT STATE LINE MINE, EAST PALESTINE.



When the coal strengthens, it is generally the upper bench that is re-enforced. Great differences in the quality of the coal are found in different portions of the mine. Like the Upper Freeport seam everywhere in Ohio, the coal, although it can be mined in large blocks, is still tender under handling. The upper bench is traversed by a great number of slate and sulphur binders, which are irregular and inconstant, but which make an element of weakness in the coal. The cleavage is very well marked, and all of the workings are carried in upon its planes. The frequency of the joints contributes to the weakness of the coal.

About $\frac{1}{4}$ of the coal goes through a screen of $1\frac{1}{8}$ inches between the bars. Of this fine coal three grades are made, viz., No. 1 or nut coal; No. 2, large pea coal; and No. 3, small pea coal. The nut goes with the lump coal into the railroad supply. The pea coal, after being

washed and sifted and divided by an ingenious method, adapted by the Superintendent, Hugh Laughlin, goes out for rolling-mill use, and for stationary engines. It makes a cheap fuel, but a considerable part of the impurities of the coal gravitates to it.

For domestic uses this coal cannot compete successfully in the markets of Eastern and Northern Ohio with the excellent seams that are there counted the standard fuels, but for steam purposes it rates deservedly high. The subjoined analysis shows it to be a strong heating coal, not excessive in ash, but rather high in sulphur. Its physical rather than its chemical qualities rule it out of competition for household fuel.

Analysis of Coal from State Line Mine. (*Lord.*)

Moisture	2.10
Volatile matter	39.37
Fixed carbon	53.46
Ash	5.07
Total	100.
Sulphur	2.87

This result is entirely in keeping with the other analyses of this seam in this portion of the State.

The mine is level free, and was one of the first in the State to introduce an endless chain for drawing out the bank-cars. The cable now runs in $1\frac{1}{8}$ miles from the mouth, and some entries are worked fully $1\frac{1}{2}$ miles beyond the termination of the cable. Mule power would be entirely inadequate to the present output under present conditions. The seam yields a little less than 2,500 tons of clean coal to the acre, and somewhat more than an acre is worked out every week.

The cover of the coal is a black slate 2 or 3 feet in thickness, over which a moderate development of the Mahoning sandstone is generally found. The protecting slate is sometimes cut away, to the detriment of the coal whenever it happens.

The Upper Freeport limestone constantly accompanies the coal, being separated from it by about 2 feet of fire-clay. The limestone is

often found as a continuous bed. The clay which is taken up in main entries is utilized in potteries located in town.

An ingenious automatic weigh-box has been contrived for the mine by the Superintendent, Mr. Laughlin. By means of it one man can weigh 1,000 tons a day without rising from his seat.

The mine is one of the largest, and one of the most economically and successfully administered in the State.

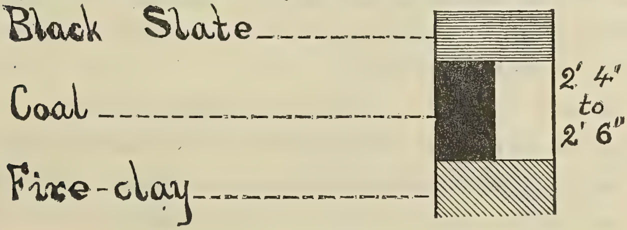
The Prospect mine of H. Suthern is worked in the same seam, and the coal is strictly continuous with that of the State Line mine.

This field is near the northern outcrop of the Upper Freeport seam, but a vast body of coal stretches away to the south and southwest from here in a continuity, that is broken only by eroded drainage channels and the occasional "wants" of the seam.

Continuous throughout this territory with the Upper Freeport seam, and with almost equal area, since the interval that separates it from the former is but 50 feet, the Brush Creek coal (No. 7 of Newberry in this district) is found in a seam of excellent character. It generally ranges in thickness from 2 ft. 4 in. to 2 ft. 6 in. It is an undivided seam when it does not exceed these limits. Sometimes it overruns them for a time, and in such case a thin parting generally is found near the bottom. It is the same seam that is worked at Salineville under the name of the Strip Vein, and at Linton under the name of the Groff Vein. It has been worked here quite largely on the Prospect property, but operations in it are now discontinued. It yields a superior milling coal, but the thinness of the seam works against its present success. The coal of this horizon is almost everywhere more highly esteemed than that of the Upper Freeport seam below it. Its structure is represented in the accompanying figure:

FIGURE XXVIII.

STRUCTURE OF BRUSH CREEK COAL (No. 7 OF NEWBERRY) AT EAST PALESTINE



The Salineville Field.

Salineville constitutes one of the older and more important mining centers of the State. It has been for 20 years a prominent contributor to the Cleveland market, and it is certain to continue a leading source of steam coal for Northern Ohio for an indefinite period.

The true order of the series is well shown by Newberry in his several reports upon this section of the State. He followed the upper portion of the Ohio River series over the low Salisbury anticlinal to their fine development in the Salineville field. A question was by sufferance counted an open one by him for a while, as to the proper name and place of the coal seam of the Empire mine, but the identification which he provisionally made has been proved true. The Big Vein of the Farmer bank has been worked through to the Ohio and Pennsylvania Company's new slope, south of town, and this in turn has been followed directly into the Empire mine, about which the question was raised. The Empire coal is the Big seam.

The two main coal seams of Salineville are therefore what Newberry pronounced them to be, viz., the Upper Freeport (Big Vein or No. 6), and the Brush Creek (Strip Vein or No. 7). Below the Upper Freeport the Lower Freeport or Roger seam is often found, but it is not invested with great economic interest in this immediate district, though it is worked at a few points.

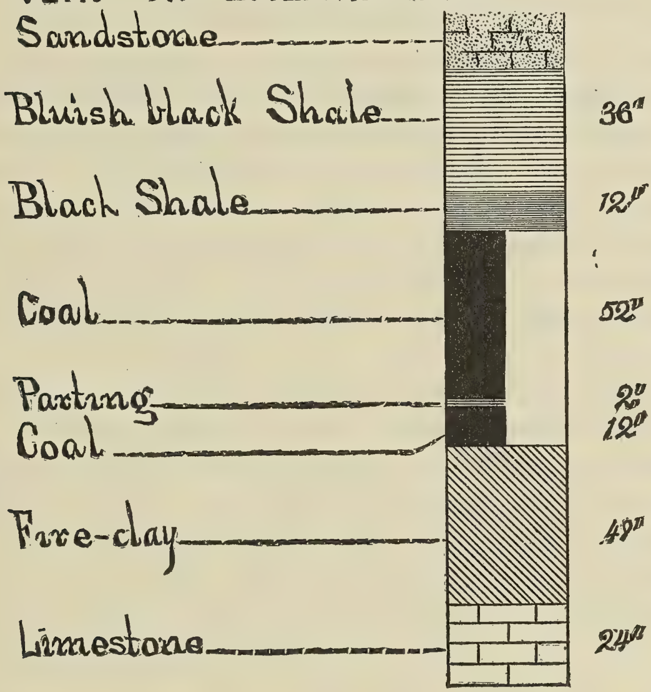
The Upper Freeport seam (Newberry's No. 6) of this region is thoroughly characteristic in its mode of occurrence and quality. It is the "Big Vein" of the district, its normal thickness reaching 5½ or 6 feet. It has a single shale parting of 1 or 2 inches in thickness, from 12 to 18 inches above the bottom, just as at Palestine, and the irregular "binders" of slate and pyrites that mark the seam elsewhere are also abundant here. The structure is represented in the following figure.

All of the statements made in regard to the physical and chemical properties of the Palestine coal can be repeated with regard to this seam at Salineville without modification. Consequently, the statements that were made as to adaptations and uses in that field are found true in regard to this district as well.

The Salineville coal is a steam coal almost exclusively. Its high percentage of fixed carbon makes it efficient in heating power.

It is coming into extensive use as a railroad coal, and bating a possible tendency to smut the flues of the locomotive, it is well esteemed

FIGURE XXIX
STRUCTURE OF UPPER FREEPORT COAL (No. 6 OF NEWBERRY) OR BIG VEIN AT SALINEVILLE



It is free from the more troublesome form of "clinker." The railroad mines are now running lump and nut coal together.

The nut coal is used to a small extent in rolling-mills, and some of the slack is coked at Salineville, but the quality of the coke fits it for heating purposes only. The coal is not largely used for domestic fuel.

At several of the mines the slack is now washed, and a marketable article of pea coal is secured. The rapidly developing economy in the use of all the products of the mine is to be regarded with great interest and favor. It does not come too soon.

The composition of the coal is fairly well shown in the following analysis (*Lord*) of the coal of the Hussey Bank of the O. & P. Co.:

Moisture	2.32
Volatile matter	39.08
Fixed carbon	52.78
Ash	5.82
Total	100.
Sulphur	2.88

There are seven mines in operation on the Upper Freeport coal at Salineville, with a daily capacity of over 1,200 tons. The territory immediately adjacent to the town is nearly exhausted, not less than 600 acres having been already worked, but a noble body of coal is now being proved, and in part developed to the northeast of the town on both sides of Tidball's Run. Enough proving has been done to warrant the statement that the supply for a long term of years is to be found in this field. It will be attacked from the valleys of the West Fork of Beaver as well as from Yellow Creek.

The Salineville Coal Company is advancing into this new territory through coal fully 6 feet thick. On the west side of its property, near the railroad, the coal is low, not yielding more than 3 feet, but the seam is at its best as it is followed north and east. Where the coal is thin, it is the bottom bench that is wanting, contrary to the usual experience.

Salineville thus appears to be located near the southern rim of the particular basin of the Upper Freeport coal, to which it gives its name. The coal runs down rapidly in height to the southeast of the village, becoming too thin for mining, within 3 miles. It does not recover its thickness in this direction until it nears the Ohio River, where another but smaller basin is reached. It also loses thickness to the west, having been opened but abandoned in Fox township; but to the southwest, as to the northeast, it holds its vólume. The axis of the basin is thus seen to extend in a northeasterly and southwesterly direction from Salineville. The Manufacturers' Coal Company holds coal of good thickness as it advances in the latter direction.

The coal of the Big Vein is sent to market after having been passed over 1¼ or 1½-inch screens. From ⅓ to ½ of the coal that is brought out of the mine comes out as nut and slack. Over an inch and a half screen, the best mining will lose ⅓ of the coal. The coal is blasted, but the quantity of powder used is not excessive. It will probably range at about 3 cents to the ton.

An effort has recently been made to utilize the slack of the seam

at the Manufacturers' Coal Company's mine, by coking it. Two grades of coke have been produced—a soft coke, designed for house fuel, and a harder coke, turned to uses in which sulphur and other impurities would not be particularly objectionable.

The soft coke yields of ash, 14.07; sulphur, 2.73.

The hard coal gives the following results: Ash, 17,47; sulphur, 3.66.

The Ohio and Pennsylvania Coal Company is also making an effort in the direction of the utilization of the slack by washing it, and sending out a pea coal that answers a fair purpose as a steam fuel in stationary engines.

The roof and floor of the coal are both characteristic in all respects. The Upper Freeport limestone is less conspicuous here than elsewhere, from the fact that seveial other limestones of the same character are fully developed in this district.

The Strip Vein or Brush Creek coal of Salineville has always enjoyed an excellent reputation in the markets which it reaches, and this reputation it fully deserves. It is a harder and purer coal than the Big Vein, and has been turned to different uses. It has always been highly approved as a milling coal, and it makes also a good domestic fuel. Its average composition is shown in the following analysis of the coal from the Anderson Bank of the Manufacturers' Coal Company (*Lord*):

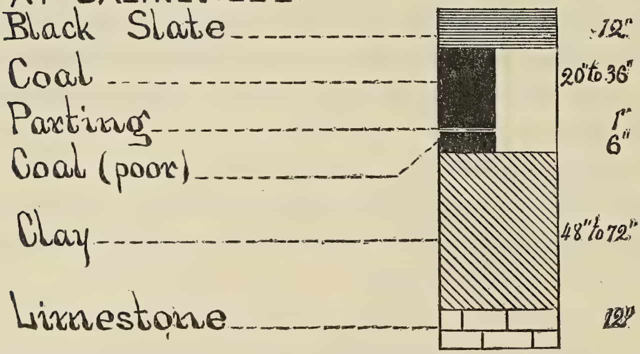
Moisture	3.26
Volatile matter	37.49
Fixed carbon	53.74
Ash	5.51
Total	100.00
Sulphur	1.21

These figures stand for an excellent coal in all respects.

The seam ranges in thickness from 2 ft. 6 in. to 4 ft., but it is counted a 3 feet seam. When it does not exceed this measure it is generally undivided, and is equally good from top to bottom. But in the heavier measures a lower bench comes in, that is an addition to the seam in measurement mainly, for its coal is sulphurous and impure. When burned it has the bad characteristic of "running on the grate." The bottom bench serves, however, for "bearing in," and thus affords

somewhat more large coal from the main seam. The structure is represented in Fig. XXX:

FIGURE XXX
STRUCTURE OF BRUSH CREEK COAL (No. 7 OF NEWBERRY) OR STRIP VEIN AT SALINEVILLE.



There have been already about 400 acres of the Strip Vein worked out in the immediate vicinity of Salineville. At present five mines are in operation with a capacity of about 500 tons daily.

The work now done, however, is small, and with the present state of the market, the seam could not now be opened. It is only where the plant is already made that the working of the seam goes forward.

It is claimed that the clays and rock between the Strip Vein and Big Vein prevent the unwatering of the Strip Vein by the withdrawal of the lower seam. If this claim is well founded, the upper coal can abide its time, but if the water is gradually lost, the air will follow and take its place, and will thus greatly deteriorate, if it does not destroy, the value of the unworked seam.

The seam holds a large area throughout the district of which Salineville is the center in Columbiana, Carroll, and Jefferson counties. This is the region of its best development in Ohio, and the only region in the State where it is mined on the large scale. Its general thickness in the county outside the Salineville field is 30 inches, but it is almost everywhere a strong, clean coal.

The Roger or Lower Freeport coal has been named as an element in the Salineville district. Its horizon is not generally reached in the immediate vicinity of the town, its normal place being about 40 feet

below the Upper Freeport coal at this point, but as the latter seam rises out of its basin along the line of the railroad to the southeastward the Roger coal comes to day, and is in good condition. It is a very bright and excellent appearing coal, 3 feet or more in thickness. It has been tried for gas in Cleveland and Ravenna with at least moderate approval. The coke made from it was not the strongest. The coal was last opened by Mr. Hutchins, of the Salineville Coal Company.

A shaft has lately been sunk to the Roger coal by the Columbiana Coal Company near its Strip Vein mine, above Salineville, but the thickness of the seam is understood to be below 30 inches, and this fact will forbid its being worked under existing conditions. The quality of the seam wherever reached about Salineville is fair.

On the west side of the county, along the line of the Cleveland and Pittsburgh Railroad, there are several small mines in the Upper Freeport coal. They find their main office in furnishing a local supply to the neighborhoods around them.

The seam is well shown at Wm. Somerville's mine near Rochester, where it has long been worked in the way already described. It is here unsteady in thickness, suffering always when reduced from the intrusion of the overlying Mahoning sandstone. Where normal and undisturbed it affords the same section as at Salineville, viz., 4 feet of coal, 2 inches of slate parting, and 12 to 16 inches of bottom coal. The character of the coal is also the same as has been already described. For household use it cannot compete on equal terms with the Kittanning coals that lie 100 feet or more below it.

The same seam is also mined at Moultrie, a few miles further north, where the same general conditions occur.

In the southeastern corner of the county, along the river front, in Liverpool and Yellow Creek townships, a good deal of coal is mined in a small way. The seams that contribute to this supply are mainly the Lower and Middle Kittanning and the Lower Freeport seams, or Newberry's Nos. 3, 4 and 5 of the Ohio Valley series.

The Lower Kittanning horizon is by far the best known and most developed of the entire series, not, however, on account of its coal, which is very impure, but on account of the great bed of fire-clay that the coal directly covers, and which is the basis of a business of great volume and importance throughout this part of the Ohio Valley.

Where the clay is mined, the coal is secured at little additional outlay, and consequently more of it comes to use than would be worked on its own account. Its quality here is generally very poor. It runs below 3 feet in thickness.

The Middle Kittanning is a thin seam, ranging from 20 to 32 inches in thickness, but its quality is excellent, and it is consequently much sought for. Dry Run, above East Liverpool, is a locality from which a large amount of this seam, thin though it is, has been taken out. The coal is bright, strong and clean. It mines large, and is consequently known as the "Block Vein" quite widely. It is the main reliance of the adjacent country for household fuel, for which purpose it is happily adapted.

The Fredericktown Anticlinal lifts this series a good deal above the river at Liverpool, and as far as Wellsville. The Dry Run coal is not largely worked in this space, though it is generally found. Openings to it have been made on almost all of the farms. At Liverpool, the Lower Freeport (Roger) coal is found in moderate development, and has been worked for a long time. The seam is but 30 inches thick, but its quality is fair. The following section is obtained at Liverpool:

	Ft.	In.
Upper Freeport limestone	3	
Interval	45	
Lower Freeport coal	2	6, Ephraim Huston's bank.
Interval	18 (?)	
Upper Kittanning coal (?) 18-inch seam	1	6
Interval	47	
Middle Kittanning coal—Dry Run seam	2	
Interval	27	
Lower Kittanning coal—Clay Vein	2	
Kittanning clay	8	
Interval to river, about	200	

The same seam is mined by Riley McKinnon, by Basil Sims, Phanuel Sims, and by Martin, Fisher, James, and Golden at different points along the valley.

Several mines are opened in the Upper Freeport seam, two miles back of Wellsville. One of the largest is on the McGough farm. The section is as follows:

	Ft.	
Mahoning sandstone	—	
Upper Freeport coal	4	
Fire-clay	4	
Upper Freeport limestone—in two courses	6	
Interval	107	
Middle Kittanning coal	$2\frac{1}{2}$	mined.
Interval	22	
Lower Kittanning coal—Clay Vein	—	

Coal is also mined in this township by Wells, Hippett, Plunkett, Boyce, and others in the several seams already named.

The general conditions of the coal supply of this part of the valley can be inferred from the descriptions now given.

In Middleton township the Upper Freeport coal is the only seam now worked. There is a large area of this coal, and the seam measures 4 feet and over. It is mined at present most largely for neighborhood supply by George Burson, Eli Guy, Uttondall Durk, and Jasper George. All these parties reside near Achor.

III. COAL MINES OF JEFFERSON COUNTY.

The lower coals of Jefferson county are closely connected in development with those of Columbiana county already described. The series is the same, and many of the elements can be described in the same terms.

The coal seams to be considered here are the following:

Brush Creek coal—Groff Vein of Linton, Finley coal of Wills Creek, Coal No. 7 of Newberry.

Upper Freeport coal—Diamond Vein of Linton, Big Vein of Hammondsville, (Wanting in Ohio Valley,) Coal No. 6 of Newberry.

Lower Freeport coal—Roger coal of Hammondsville and Ohio Valley, Shaft seam of Steubenville, Coal No. 5 of Newberry.

Upper Kittanning coal—Eighteen-inch seam, seldom opened.

Middle Kittanning coal—Block Vein, Strip Vein of Hammondsville, Coal No. 4 of Newberry.

Lower Kittanning coal—Clay Vein, Potter's Vein, Sulphur Vein, Creek Vein, etc., Coal No. 3 of Newberry.

The records of the Wellsburg and Brilliant gas-wells that have been drilled within the last year will add to this series, if they are accepted, a 6 feet seam of coal that was reported as passed through about 450 feet beneath the Shaft seam. The value of the records depends on the care with which they were kept, and the discernment with which the work was followed. Without more knowledge than is now in our possession, it would not be safe to identify this seam as the Sharon coal of the general scale. It can, however, be said that the reported coal is just about where geology would locate this bottom seam, if required to find a place for it. The intervals would range as follows:

	Ft.	
Lower Freeport coal—Shaft seam.		
Interval	100	(90 to 120 ft.)
Lower Kittanning coal.		
Interval	50	
Ferriferous limestone.		
Interval	300	
Sharon coal.		

The good faith of the record is not questioned, but so anomalous are the facts reported that judgment may well be suspended until the claim shall be rendered more probable or less so by the rapidly accumulating facts of the same order. A basin of Block coal under the Freeport, and even under the Pittsburgh coals would be a fact without a parallel in our geology so far.

In regard to the Lower Kittanning coal in Jefferson county, nothing needs to be added to the statements already made as to this seam in Columbiana county. All the facts and conditions reported there are exactly duplicated here. The clay is very extensively worked from Port Homer as far down the river as Toronto (Sloan's Station), and the coal comes out to some extent with it, but it is never valued highly, nor would it often be sought on its own account.

The Middle Kittanning coal (No. 4 of the Ohio Valley, and No. 6 of the Tuscarawas Valley) has been worked at but a single point in the county to any considerable extent. It constitutes the Strip Vein

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NOTE.—Since writing the above, Albert Smith, who is drilling the gas-well for the Jefferson Iron Works at Steubenville, has informed me that he kept close watch when passing this horizon, and found a considerable bed of black slate at a depth of about 650 feet, but not a particle of coal. He found no coal, in fact, below the Clarion horizon.

at Hammondsville, and despite its small measure, it was for a number of years worked quite extensively, on account of the very hard and firm coke produced from it.

The Hammondsville coke outranks all Ohio cokes in these respects, but it is high in ash and sulphur. The manufacture has dwindled to very small proportions now, but the output of a handful of miners is still brought to the ovens.

The coal does not exceed 30 inches in thickness, but it is very bright and strong. In ash it runs rather high, but the figures obtained by Wormley (vol. III, p. 779) can scarcely have been derived from average samples. The following analysis shows the composition of the coal as determined by the methods here employed :

Hammondsville Strip Vein	*Lord.*
Moisture	1.89
Volatile matter	37.17
Fixed carbon	53.67
Ash	7.27
	100.
Sulphur	0.72

The coke of this seam gives for a single specimen, and possibly an inferior one :

Ash	19.51
Sulphur	3.36

This seam is opened at many other points along the Ohio Valley, but only in farmers' banks, not in mines.

The Upper Kittanning (?) or eighteen-inch vein is quite steady through this field, but it does not add to the resources of the county.

The Lower Freeport seam is decidedly the most important of the coal seams of Jefferson county. It long ago acquired at Hammondsville a local name by which it is widely known throughout Eastern Ohio, viz., the Roger coal, but it is under another name that it has acquired its best reputation, viz., the Steubenville Shaft coal. It is a seam of fair volume at Hammondsville, measuring 3 feet and over. It has one slate parting, which is generally a few inches from the bottom, but sometimes at or above the middle of the seam. It is too impure,

as a rule, to go into the general market, but there are many localities where the quality is good. It is on the whole very steady, but it is, of course, sometimes wanting where it is due. In the high rocky bluff overhanging Yellow Creek Station, for example, the place and the clay of the seam are clearly shown, but there is not a trace of coal.

Along the Ohio Valley the Roger coal has been worked at many points. It is found in every neighborhood in which there has been a considerable demand for coal. Mines are opened in it at Elliottsville, at Toronto, and at numerous other points. It holds a thickness of 30 inches and upwards. On the West Virginia side of the river, in the valley of King's Creek, it grows stronger, reaching a measure of $3\frac{1}{2}$ feet, and even 4 feet. It gradually falls along the southward course of the valley, until it comes to water level at Will's Creek. Beyond this, it becomes the Steubenville Shaft seam, finding here its finest development, and taking rank with the best seams of the State. From Steubenville, the coal passes to the north and west under heavy cover. When its horizon is next reached in the valleys of Yellow Creek, on the north side of the county, the coal is again found in excellent condition, though somewhat thinner. There seems reason to believe that Cross Creek, Island Creek, Salem, Springfield, Ross, and Knox townships are underlain with this important seam.

The Upper Freeport coal is of very little value in Jefferson county, outside of its development in the northeast corner, in Saline, Ross, and Knox townships. In the two latter it is not known to be of great value.

Only one important mine is now in operation in this seam, viz., the Diamond Coal Company's mine, at Linton.

West of the Ohio River, and south of Yellow Creek, it seems to fail absolutely for a large district.

Its limestone and clay are everywhere shown, and are occasionally worked, but the coal dies almost without a sign.

The Diamond Coal Mine.

This well-known body of coal, the thickest in the region, situated at Linton, just above Yellow Creek Station, on the Cleveland and Pittsburgh Railroad, stands by itself among the coal mines of the county. There are several anomalies in its structure and associations, and it is but recently that some of the most perplexing of them have been satis-

factorily accounted for. Newberry first referred the Diamond coal to its true horizon, viz., that of his Coal No. 6, or the Upper Freeport seam, but on this identification, an unusual disparity of intervals was found between the elements on the Diamond property and on contiguous territory. The section on the former is as follows:

	Ft.	In.
Brush Creek coal—Groff seam.		
Interval, including Mahoning sandstone	61	
Black slate	0	8
Diamond coal	7	(3 to 9 ft.)
Interval	90	
Middle Kittanning coal—Strip Vein	$2\frac{1}{2}$	
Interval	22	
Lower Kittanning seam—Creek Vein	3	
Kittanning clay.		

But at Hammondsville and at Collinwood, and in fact throughout the valley generally, the same elements occur in the following general order:

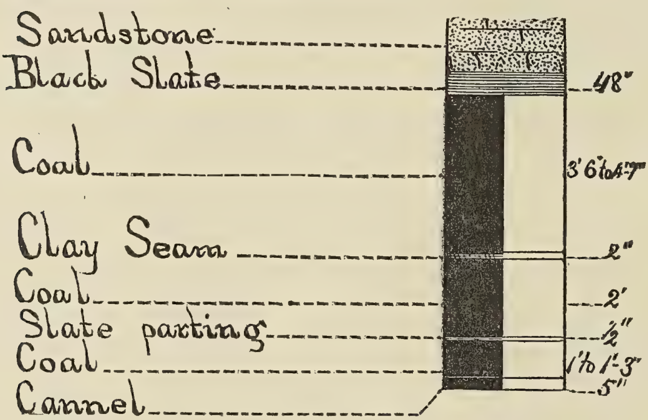
	Feet.
Brush Creek coal—Groff Vein, No. 7	3 to 4
Brush Creek limestone.	
Interval (from coal to coal)	67
Upper Freeport coal—Big Vein, No. 6	0 to 6
Upper Freeport limestone and clay	6
Interval (from coal to coal)	61
Lower Freeport coal—Roger Vein, No. 5	$2\frac{1}{2}$
Lower Freeport limestone.	
Interval (from coal to coal)	72
Middle Kittanning coal—Strip Vein	$2\frac{1}{2}$
Interval	20
Lower Kittanning coal—Creek Vein	3
Kittanning clay.	

Comparing these sections, we find that the interval between the Strip Vein and the Big Vein in the first is 90 feet, and in the second 133 feet. The Diamond coal was thus brought nearer to the place of the Roger Vein than to that of the Big Vein, and in addition it was noted that the Roger Vein was not present on the Diamond property. It was hard to understand how so great a descent of the Upper Freeport coal swamp could be made so abruptly. Though this difficulty still remains, the recent workings of the mine remove all questions as to the fact. The coal has been found in the north entry to climb a hill

as steep as is to be seen in any mine of the State, and to gain all the elevation required to make it normal, within 150 yards of the lowest portion of the mine. The interval from the Strip Vein to this portion of the mine is not less than 140 feet.

In structure the Diamond coal agrees in its uppermost 6 feet with the structure of the Big Vein at Salineville and elsewhere, as is shown in the annexed diagram:

FIGURE XXXII.
STRUCTURE OF DIAMOND COAL SEAM AT LINTON.



The progress of the mine has shown that this upper portion is in reality the normal seam, and that the increase in thickness of this mine over other Big Vein mines in the neighborhood is to be found in the bottom bench. This sometimes rises to 1 ft. 8 in., and to this extent the Diamond coal is re-enforced beyond the Upper Freeport measures. The coal in the deepest swamp of the mine has been known to measure 9 feet, but it does not often rise beyond 8 feet. The average of what is now worked would be about 6 feet. When it grows thin, as it does in every direction from the "swamp," the bottom bench shrinks, and finally disappears altogether.

In the center of the "swamp" of the mine, a bottom bed of cannel, 4 to 6 inches in thickness, is found, which is of wonderful paleontological interest. More than 50 species of fishes and reptiles have been

collected here by Newberry, almost all of which are not only new to science, but almost all of which are confined to the acre or two of cannel that lies in the center of this mine. They have never been found elsewhere. Newberry justly says of this locality, "there are few places in the world more interesting to the paleontologist than the Diamond mine at Linton, since we get here such a view of the life of the carboniferous age as is afforded almost nowhere else." The field will soon be exhausted.

So far as the workings and explorations have now proceeded, it appears that the basin of the Diamond coal has its longer axis in the direction of S. 65 W., this axis having a length not to exceed 800 yards, while the greatest breadth would not be more than half this distance, and approximately at right angles to the main axis.

The coal is anomalous in this further respect, that it does not rest on a fire-clay. The cannel above named has underneath it a hard and irony band in many instances, and in no case in the center of the basin is there the slightest hint of fire-clay. So firm a bottom allows the pillars to be reduced to small dimensions. Nine feet square is counted ample to support a heavy hill permanently, the rooms being worked 21 feet wide.

The mine has been open for a long time, having been worked for neighborhood use before railroad transportation was available. There are no surveys that show how much has been worked out, but the estimate of the present owners places the exhausted area at 45 acres.

At the present output of 275 to 300 tons per day, there is not a long term to the thick coal. The seam has not yet been followed below 3 feet, but at the present writing, the northeast entry, which is furthest under, has gained a foot of coal after passing the lowest point on the top of the "hill." Whether a second basin exists in this direction will soon be learned. The indications from outcrops are not favorable to such a view.

The physical and chemical properties of the coal agree with those of the Upper Freeport seam, as generally found in this region. The descriptions of the Big Vein at Salineville would require no modification here.

An analysis of the average output gives the following results:

Diamond Mine, Linton	*Lord.*
Moisture	1.67
Volatile matter	39.28
Fixed carbon	52.16
Ash	6.89
Total	100.00
Sulphur	3.43

Strong heating power is indicated in the analysis, and realized in the consumption of the coal. The product of the mine is turned exclusively to railroad use, the Pittsburgh, Fort Wayne and Chicago Company taking the whole output. The coal is counted equal in strength to any with which it comes into competition. The "run of mine" is now taken by the railroad company, the coal being "raked" in the rooms before being loaded into the small cars. So far as known, this mine is the only large mine in this portion of the State in which the rake is now employed. No troublesome clinker is reported in the burning of the coal.

At Irondale the same seam has been worked to some extent in past years, but the mines are not now in operation. There is no reason to doubt that work will sometime be resumed in this field, however, as there are valuable basins of coal known to exist here. The usual unsteadiness of the seam is experienced in the workings of this neighborhood, the seam passing from 6 to 3 feet with rapid alternations.

The Brush Creek coal (No. 7 of Newberry) has a fine development throughout Jefferson county. It acquired the local name by which it is best known, viz., the Groff Vein, from the Groff farm, at the mouth of Yellow Creek. It has been worked there for many years, and the mine is still open. The seam is here 4 feet in thickness, the largest measure that it anywhere acquires. It holds this measure or at least nearly enough to be designated the "4-feet seam," to the very western boundary of the county. The quality is everywhere excellent. It burns freely, leaving nothing but fine ashes. It is a favorite household fuel wherever it is accessible.

There are numerous small mines in the seam along the valley, as at Elliottsville and Toronto, and elsewhere, but more important districts are found on Island Creek, where the coal is known as the Finley coal, and on the upper waters of Yellow Creek, near Nebo, in Springfield township, where the coal is known as the Dorrance coal. The seam measures fully 3½ feet in both regions, and is fairly steady and regular.

The character of the Finley coal is shown in the following analysis:

Finley coal, Will's Creek	*Lord.*
Moisture	1.80
Volatile matter	40.60
Fixed carbon	52.54
Ash	5.06
Total	100.00
Sulphur	2.62

The coal is hard, bright and clean, and this seam, next to the Lower Freeport, is the main reliance of the county, so far as the lower coals are concerned.

There is a good deal of territory in which the Brush Creek coal exceeds the Lower Freeport in value. The value of this seam is, of course, greatly enhanced by the fact that the Upper Freeport disappears from the scale so abruptly and absolutely for the greater part of the county.

The importance of the Steubenville coal field is so great that a distinct and somewhat extended description of its present state will here be given.

The Steubenville Field.

This is one of the oldest and best-known of the Ohio coal fields. Its main element is the seam known as the Steubenville Shaft coal, which has been shown in the preceding chapter, p. 62, to be the extension of the Roger coal of Columbiana county, and the Lower Freeport seam of the general section. The first shaft was sunk to it in 1855, but it was 6 or 8 years after this before the mining of the seam acquired considerable proportions. A seam that lies from 28 to 45 feet below the Shaft coal has been reached in a number of the mines, but though its thickness is good, a maximum of 4 ft. 10 in. being reported, its value has not yet been well established. The tests already made do not indicate a coal of the best character, but a shaft is now being sunk to it in the Averick mine (Ohio and Pennsylvania Coal Company), and a thorough test will be made of its quality and adaptations. It appears to be the *Upper Kittanning* coal of the Pennsylvania series, which is known through the Ohio Valley, above Steubenville, as the eighteen-inch seam, and which rarely exceeds the measure that its name indicates.

Another element of conspicuous value in this field is the Pittsburgh coal, which is found in the hills opposite, and also below Steubenville, whenever a proper elevation is reached. The seam has a thickness of not less than 5 feet, strengthening to 6 feet in much of its territory.

There are several other thin beds of coal in the Steubenville region, as for example,the seam that lies near the Crinoidal limestone, and also a seam that lies 20 to 30 feet above the Shaft coal in some places, but the Shaft coal and the Pittsburgh seam constitutes at present the sole resources of the district, so far as coal is concerned.

The Shaft coal will be first described. It becomes a shaft seam, as will be remembered, south of Will's Creek. At this last-named point it lies at the level of the river, but it soon rises above railroad grade as it is followed northward, and is well up in the hills at Toronto, and above in the Ohio Valley.

It dips slowly to the southward through Steubenville, and the varying depths of the shafts depend mainly upon the elevation of the points at which they are sunk. The range of depth is from 75 to 261 feet.

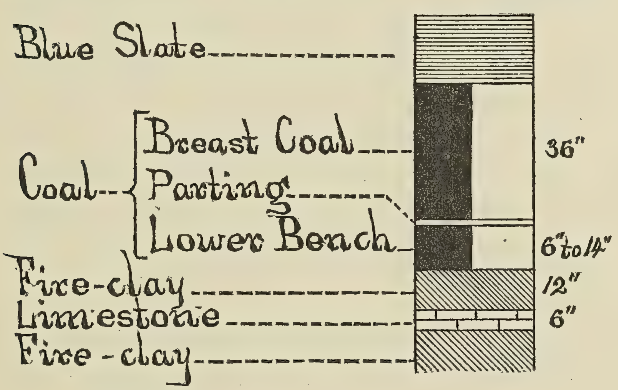
The seam has been followed as far south as Rush Run, 11 miles below Steubenville, where it is mined. To the westward it runs everywhere under heavy cover, and it is not known to rise to day in any thoroughly characteristic showing. It has not been mined on the south side of the river until recently, but its presence has been proved there in various ways by borings, and also in one instance by being followed partly across the river in one of the Steubenville mines. A shaft has recently been sunk to it in Wellsburgh, West Virginia, the coal being found in full thickness. Its area is thus seen to be indeterminate, and the main fact that can be given in this connection is that it extends as a shaft seam for about 14 miles along the river front. The mines have been carried westward in unbroken coal for more than a mile in a number of instances. It is thus evident that a large area is to be found here. The best available calculations show, that from 1,000 to 1,200 acres have been already worked out.

The thickness of the seam throughout the district ranges from 3 to 5 feet. The ordinary and perhaps the average thickness is 4 feet. The coal has never been persistently worked where it falls below 3 feet. There are large areas where it holds a thickness of more than 4 feet, but it is properly described as a 4-feet seam. At the Boreland Shaft it

is left 3 ft. 4 in. and 3 ft. 6 in. in some entries, and at the Mingo Shaft, which adjoins the Boreland property, the coal fell to 2½ feet in thickness, or to even smaller measure than this, and the mine was therefore abandoned, but to the southward the seam increases again, being found 5 feet thick in the Brilliant Shaft, 3 miles below, and the same in Rush Run Shaft, which is 11 miles below Steubenville.

The structure of the seam is quite constant. There is a slate parting from 6 to 14 inches above the bottom. This is the only regular division in the seam. The lower bench of the coal is more variable than the upper. The ordinary contractions and expansions of the seam are mainly confined to it, the upper bench or "breast coal" running very steady and uniform. The structure is represented in the following figure:

FIGURE XXXI
STEUBENVILLE SHAFT COAL.



The roof of the coal consists normally of a hard blue slate or soapstone. It is sometimes replaced by sandrock, in which case the coal always suffers in quality, and generally in thickness. The regular roof is sound and excellent in all respects. It constitutes one of the main features, in fact, in the working of the coal.

A thin coal seam has been spoken of above the Shaft coal. In the lower mines of Steubenville this seam is 22 feet above the Shaft seam, and about 6 inches thick. It gradually falls toward the coal below it, until on the northern boundary of the Market Street Shaft mine, it

comes directly down upon the latter, adding itself to the normal thickness of the seam. It is said to hold this relation in all the northerly mines of the town. The quality of this rider is not good, and its coal is rejected. Whenever it comes within 2 or 3 feet of the main coal, it makes a bad roof, the shale below it replacing the normal cover, and proving treacherous. There are but few cases in which the Upper Freeport sandstone attacks the coal, but occasionally the protecting shales are entirely removed.

The coal rests on about 4 to 10 feet of fire-clay, in which the bowlders of the Lower Freeport limestone are bedded, the uppermost of them being within one foot of the coal. The limestone is hard and stubborn, some of it being charged with iron, and much of it being silicious. Some blocks are found of a fair degree of purity as limestone.

The floor of some of the mines is subject to "creeps," and in the worked-out rooms it often rises to meet the roof without any break in the latter.

The coal is bright and cubical, but it is of rather a tender nature. Its joints are even and regular, but they are numerous, and divide the coal into small blocks, to which fact its weakness is mainly due. Although a tender coal, it cannot be profitably mined without the use of powder. The result is that it mines small. In the Steubenville mines, under the system of mining now in force, by which the miner is paid for his coal before it is screened, never less than one-third, and generally one-half of the coal that is sent from the shaft comes out as slack and nut coal.

The coal is of the cementing variety, and it makes a coke of fair strength and character. All of the small coal and slack has been utilized in this way, hitherto. The amount of visible "sulphur" or pyrite varies in different parts of the seam, and also in different portions of the mines. The bottom bench is more impure than the breast coal, but the larger balls of pyrite lie near the roof. Like the Freeport seams generally, this coal ranges rather high in sulphur, as will be seen in the appended analyses.

In the following table the analysis of the coal from a representative mine is given:

Coal of Market Street Shaft, Steubenville .... (*Lord.*)

Moisture	2.06
Volatile matter	39.06
Fixed carbon	53.96
Ash	4.92
Total	100.
Sulphur	1.79

The figures given above fully confirm and justify the good reputation of the Steubenville Shaft seam.

The coal has always been rated high as a rolling-mill coal, burning with considerable flame, and giving out its heat quickly. On the same account it is an excellent steam coal. For domestic use it is the sole reliance of the city of Steubenville, but it has not yet established a place for itself in the general market. The fact that it does not bear handling well, works against it, in this respect, as does also the fact that the miner is paid for unscreened coal. So long as the coke was in demand for the furnaces of Steubenville and vicinity, the quality of the coal produced, so far as size was concerned, was a matter of no consequence, the whole product of the mine going in some instances directly to the ovens. But recently a new state of things has been brought about. Though the Steubenville coke is an excellent fuel, it cannot compete successfully with Connellsville coke in the manufacture of iron, and it has been displaced even in its own field by the latter. Add to this the fact that the rolling-mills of the valley are making use of the great supplies of gas that deep wells are now reaching, in place of the coal, and it will be seen that two of the largest demands upon the mines are being withdrawn, and if their production is to be maintained, it must be through the establishment of an outside market. Such a market it can gain only in competition with some of the best coals of the Allegheny field, and it will require sagacious management in all respects to maintain the mines in uninterrupted activity. But even though conditions should prove temporarily unfavorable, there can be no possible doubt as to the ultimate value of this noble coal field.

Within the limits of the general field, thirteen shafts are now sunk to the Steubenville coal.

Beginning at the north, we first find the Cable Shaft, from which very little coal has been taken.

The Alicanna Shaft is next below. The mine is connected with a rolling-mill, but both are idle at the present time, and the mine is

filling with water from the river. The coal is 5 feet thick, and but few acres have been so far taken.

The shaft of the Jefferson Coal and Iron Company, commonly known as Bustard's Shaft, is next in order. Quite a large amount of coal has been mined here, and the seam has the same thickness as above.

What is known as the Gravel Pit Shaft lies next below. It holds a good 4 feet of coal, and has produced a considerable amount.

The Stony Hollow Shaft of the Market Street mine has been abandoned, but not through any defect of the coal. In the adjoining mine of the same company, viz., the Steubenville Coal and Coke Company, one of the best bodies of the Shaft coal has been found. Its entries extend through unbroken coal for more than a mile from the mouth of the shaft, and the seam holds its thickness of 4 feet with almost perfect uniformity, the only deviation being in the way of occasional increase.

The mine of the Jefferson Iron Works, known as the Rolling-mill Shaft, exactly agrees with the property just described, against which it abuts. A large acreage has been removed from this mine also.

Averick's Shaft, now leased by the Ohio and Pennsylvania Coal Company, is next below. Its coal is of the same thickness, and is in no way inferior in quality. It has been worked largely, but not to the same extent as the mines last described.

The next mine below is that commonly known as Boreland's Shaft, but it is now operated by the Jefferson Iron Works, and is known as their Shaft No. 2.

The coal is somewhat thinner in this mine, at least in its southern extension, than in the mines already reported. It comes down to 3 ft. 6 in., and to 3 ft. 4 in., and on its southern boundary is disturbed by clay veins and other irregularities. The seam generally is remarkably free from troubles of this sort. This mine has produced a large amount of coal, as good in quality as any in the field.

According to the best available testimony, not less than 1000 acres of coal have been worked out in the Steubenville mines.

The "trouble" in the seam at the southern boundary of the last-named mine seems to extend into the territory of the Mingo Shaft, which adjoins it. Coincident with this fact, there is a serious diminution in the volume of the coal, the measure running down to 30 inches and less, for most of the property which the entries have traversed.

Coal of this thickness cannot be mined from the Steubenville seam under present conditions.

The next opening to the coal is in the shaft located at the village of Brilliant, formerly La Grange, 3 miles below Mingo Junction. The coal has here regained its full volume. It is 5 feet thick throughout most of the mine, and of the usual quality.

At Wellsburg, on the West Virginia side, a shaft has recently been sunk, and the coal agrees exactly in character with the seam at Brilliant.

The last shaft that reaches the coal is located at Rush Run, 5 miles below Brilliant, and 11 miles below Steubenville. Inasmuch as this is the furthest proved extension of the seam in this direction, a more detailed account will be given of this mine, to serve as a guide for future exploration and development.

The depth of the shaft is 265 feet. The dip of the coal is reported as east and *northeast.*

The coal was found 7 feet thick at the bottom of the shaft, but only 5 feet were taken, one foot being left for roof, and one for bottom, the portions left being in both places inferior in quality.

"Trouble" was experienced in driving the entries to the northward. Clay veins were met, and also "wants" in the coal. At one point the seam fell to 2 ft. 4 in. for 20 yards, but it recovered itself beyond. At another the coal suffered from a clay vein for 300 yards. The thickness at the extreme point to which the workings were carried was 4 ft. 6 in., but under the westward entries only 4 feet was held. The band of poor coal covering the seam at the shaft disappears altogether in some directions, and the normal slate makes the roof. In other parts of the mine the roof was what is termed by the miners *post,* a hard and white sandy clay, connected apparently with the irregularities of the seam already referred to.

Two parallel entries were advanced under the river for 150 yards. The coal was strengthening in this direction, the bottom coal measuring 2 ft. 6 in., and the breast coal 4 ft. 6 in., the whole seam showing an excellent appearance.

The coal yields coke of the usual Steubenville standard. In all respects, quality of coal, parting, floor and roof, it holds well to the characteristics of the seam, as shown at Steubenville.

The mines of the Steubenville district, like many other shaft mines,

are liable to fire-damp, and require special care in ventilation, in order to be worked in safety. But from the first, they have been in the hands of competent and care taking men, and thus destructive accidents have been avoided. The system of ventilation in operation is excellent, and a full current is kept up to the working faces day and night. The entries and working faces are traversed every morning by an inspector before a miner is allowed to descend. The Market Street Shaft is counted, in all its management, as one of the best ordered mines of the State. It has been under the charge of William Smurthwaite for 20 years, to whom the Survey is indebted for many of the details already given.

The coal seam below the Shaft coal has always been found to abound in gas. Whenever it has been struck, a strong current has been found to issue from it. In some cases the supply has been utilized.

The Nebo Field.

Some new explorations have been made in the valley of Yellow Creek, in Springfield township, near Nebo, where the entrance of a line of railroad has led to quite careful examination so far as the coals are concerned. The order of the strata at this point is clear and intelligible. The following section was obtained there:

13.	Crinoidal limestone, not seen, but found in adjacent hills.	
	Interval	30 to 50 feet.
12.	Second red clay band.	
11.	Interval—chiefly blue and black shales with occasional sandstone ledges	229
10.	Brush Creek coal—Groff Vein, No. 7	3½
	Fire-clay	2
9.	Brush Creek limestone	2
8.	Mahoning sandstone and sandy shales	34
7.	Upper Freeport limestone, massive and brecciated	1–4
6.	Upper Freeport or Bolivar clay—white, red and blue	6
5.	Shales	9
4.	Sandstone, Upper Freeport	18
3.	Shales	4
2.	Lower Freeport or Roger coal	3
1.	Shales with calcareous nodules	6

The section is continued downwards until both of the Kittanning coals, the Strip Vein and the Creek Vein, of the Hammondsville region, are struck. Several borings have been made, and more are going forward. One of these borings in progress at this date, made under direc-

tion of Mr. William Hemingray, by Simon Shetlar, on James Kelly's farm, on the north side of Yellow Creek, gives the following record:

	Ft.	In.
Lower Freeport or Roger coal	3	1
Sandy shales—beginning about on level with bottom of coal	10	
Blue sandstone	18	
Dark-blue sandstone	22	
Flaggy sandstone	4	
Bastard slate (sandy)	17	
Black slate	1½	
Coal, Hammondsville Strip Vein	3	
Fire-clay	1	
Blue rock	5	
White clay	4	
Dark shale	9	
White sandstone	14	

The lower coal may be cut out at this point. If present it will be reached within a few feet. The measurement from the Roger to the Strip Vein is 75½ feet, or just about the measure on the outcrop. Tradition has located a thick seam of coal at this point. Salt wells have been bored at various localities along the valley, and from their crude records, handed down orally, a firm conviction is entertained by many of the best informed residents that a 7 feet seam of coal is within easy striking distance. There seems little to warrant such a belief, as the Middle Kittanning coal does not assume these proportions in this section of the State, but if 3 feet of it exist here of the character that it generally maintains, it will doubtless become a source of profit at no distant day.

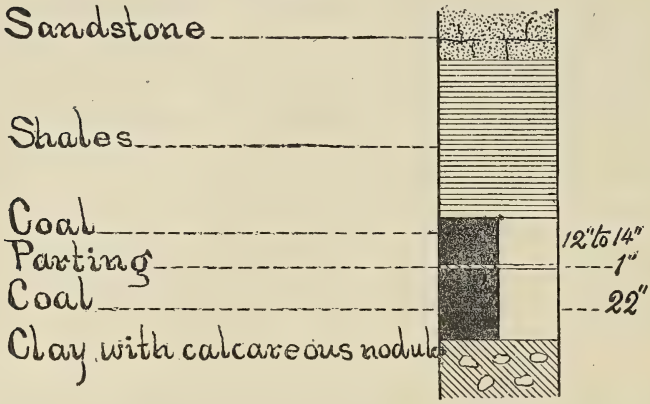
The Roger coal lies just above drainage through all this region. Its quality is fair, as is seen from the following analysis:

Lower Freeport Coal, Nebo .... (*Lord.*)

Moisture	2.15
Volatile matter	39.45
Fixed carbon	50.10
Ash	8.30
	100.
Sulphur	2.84

The structure of the seam is as follows:

FIGURE XXXV
STRUCTURE OF LOWER FREEPORT COAL AT NEBO.



The seam shows very great steadiness here, which goes some ways towards compensation for its light volume. It is opened everywhere, and everywhere shows the same structure and thickness. It seems reasonable to believe that the coal extends straight on to the river where it is the famous Shaft seam, with, no doubt, occasional "wants."

The parting in the seam is higher here than at Steubenville, and the coal is more blocky and stronger, but it is at the same horizon without doubt.

The entire absence of the Upper Freeport coal is to be noted in the section given. The limestone and clay are very steady, and very characteristic, but there is not a hint of coal. The same line of facts, it will be remembered, exists at Steubenville. The Big Vein must then be dropped from the resources of the district. To compensate for this in part, there is found in the Dorrance coal a fine development of the Brush Creek seam. It is $3\frac{1}{2}$ feet thick where measured, and is known as the 4 feet seam. It has no parting. The coal is not, however, steady, but in a few openings that have been made on the Kelly farm has proved quite the contrary. Good areas of it, however, are sure to be found. The quality is of the usual excellence. These three seams, a $3\frac{1}{2}$ feet seam that is of excellent quality, but unsteady, a 3 feet seam that is unusually steady and of fair quality, and a possible 3 feet seam, to

be reached by a shaft of 75 feet, the last-named seam likely to be a coking coal of high grade, would seem to constitute the coal resources of the Nebo field.

Gas wells are easily obtained here, and indications point to a fairly permanent supply. Salt water is also within easy reach.

To establish the fact that the Nebo coal is the Roger seam, a line of sections was run from Hammondsville to the above-named locality. The exposures were all that could be desired, and the identifications of the notable elements are positive and unequivocal. The intervals are either steady and normal, or else they change gradually so as to leave no obscurity in the sections.

At Hammondsville, five coal seams are well shown, as represented in Fig. XIII. All of these but the Groff seam go below drainage in the great southern bend of Yellow Creek, south of Hammondsville. The valley has an easterly direction for a little while, leaving the strata level. It then ascends in a northwesterly direction and the strata gradually rise, bringing the Roger coal out of cover not far below the mouth of Brimstone Run. From this point to Nebo, the course is again east and west and the strata rise with the valley, the Roger coal holding its place a few feet above drainage—all of the way.

From Hammondsville to Saltsman's, the Upper Freeport coal (Big Seam) is thin and worthless. It mends somewhat here and averages 3 feet in thickness as far as Moretown, and the quality is good. From the last-named points westward, it has no value, and though its limestone and fire-clay continue, as at Nebo, there is scarcely a black mark to stand for the coal. The Brush Creek seam comes and goes, but the Roger seam is found where it is due, and wherever it is shown, it is clean and bright and regular.

The Lower Coal Measures of the first tier of counties on the eastern border of the State have now been briefly described. The chief centers of production have been noted, and the general conditions under which the coal exists and is mined have been pointed out.

The same line of facts will be taken up for the same measures in the counties next in order, viz., Portage, Stark, Carroll, Tuscarawas, and Guernsey.

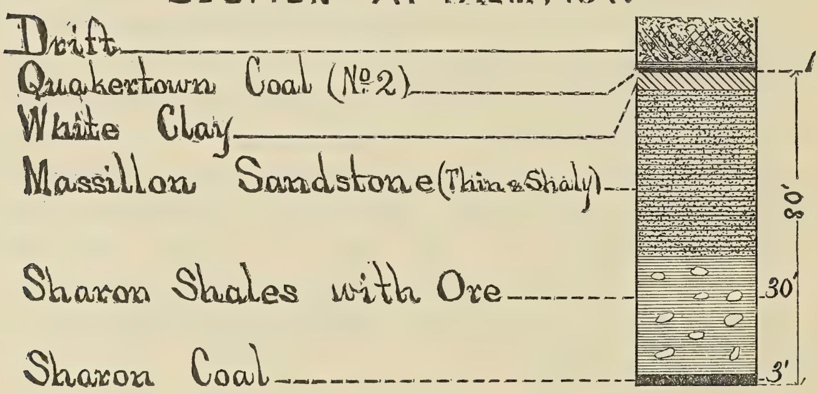
IV. COAL MINES OF PORTAGE COUNTY.

Passing westward from northern Mahoning, we come into Portage county. Although most of its area lies within the coal measures, it has comparatively little of economic interest in its geological scale, so far as known. Nothing has been added to our knowledge of its resources since Newberry's report, in vol. III, except in its one productive coal field, that, viz., located in Palmyra.

A valuable basin of the lowest or the Sharon coal, agreeing in all respects with the Mahoning Valley deposits, has been known to exist in Palmyra for a number of years. It lies due west of the Austintown field, and is about 20 miles distant from it. It is connected with the latter by some small intervening basins, now mostly exhausted.

The general order in this region is well shown in the following section, taken near the Scott mine, in Palmyra township:

FIGURE XXXIII
SECTION AT PALMYRA.



The present condition of the field is as follows: Three mines are in operation at Diamond, one mile east of Palmyra Center. They belong respectively to the Palmyra, the Black Diamond, and the Scott Coal Companies. Their combined capacity ranges from 750 to 1,000 tons per day. The output is very much less. The railroad on which they are located is narrow gauge, which fact compels reshipment of the coal before reaching any large market, and thus puts them to disadvantage. The royalty is also heavy, ranging from 25 to 40 cents per ton.

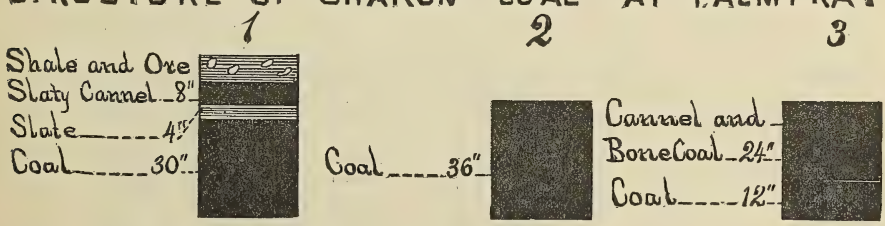
As in the Block coal fields generally, the Palmyra coal lies in narrow troughs or swamps, the length of which is considerable in proportion to the breadth. In this field the troughs are often very narrow, and never exceed 200 yards in breadth. They are somewhat sinuous, but the general direction is northeast and southwest. Mr. E. T. Bowen, the intelligent manager of the Palmyra Coal Company, has observed that whenever a sharp deflection in the course of the swamp occurs, there is a good body of coal to be found in the concavity of the curve.

It would be hard to state the average thickness of the coal. Three feet are assumed as the normal thickness of the seam, and for mining all coal below that, a larger price is paid per ton. The coal is worked down to 2 feet, and sometimes to 1½ feet. The coal in the Black Diamond mine is a trifle stronger than in the other banks. In a considerable part of the Scott mine it is thinner than elsewhere. In the Palmyra and the Black Diamond mines, a thin "bone" coal comes in at the top of the seam, but in the Scott bank this develops into a semi-cannel, 1½ feet thick. It is called Splint coal, and market has been found for it to some extent. It has even been sold at a higher price than the block coal.

The normal section of the seam is 3 feet of clean and undivided coal, but this structure is varied in several ways. Frequently there is 2½ feet of coal, overlain by a 4-inch slate, over which 8 inches of slaty cannel occurs (No. 1, Fig. XXXIV). Again, the true coal may be reduced to 12 or 14 inches, with 2 feet of cannel overlying it (see No. 3 of figure). All these facts are shown in Fig. XXXIV:

FIGURE XXXIV

STRUCTURE OF SHARON COAL AT PALMYRA.



These several phases occur in different entries of the Scott mine. The cannel has a brecciated structure at times. The thickest coal ever

reached is 4 ft. 5 in. In this case the 4-inch slate dies out, and the cannel band becomes coal.

The coal is taken without powder. It is strong, and mines large, the Black Diamond coal having a little advantage in this respect also. Ordinary mining makes about 1 ton of nut to 8 tons of lump coal, and 1 ton of slack to 4 tons of lump. The nut sells close to the lump coal for domestic use, and the slack can be made to pay its way to market at least. The screens employed are $\frac{7}{8}$ inch at Scott's, and $1\frac{1}{4}$ inches at the other banks. The whole area of coal belonging to the several mines will aggregate perhaps 100 acres, the Scott mine having about as much acreage as the other two combined. A number of acres have been worked out, but no reliable estimate is at hand.

There are other tracts of the coal in the vicinity. West of Palmyra a tract of perhaps 50 acres has been proved. It was in fact the first large body of the coal that was struck in the explorations of 25 years ago. Lacking facilities for transportation, the property is undeveloped.

A new basin is now being tested by sinking a shaft, $1\frac{3}{4}$ miles southeast of Diamond, by H. H. Gillingham and Company. The promise seems fair for a deposit of some value.

The composition of the Palmyra coal is shown in the following analyses (*Lord*):

1. Palmyra Coal Company.
2. Scott Coal Company.
3. Cannel bench, Scott mine, bottom.
4. Same, middle.
5. Same, top.

	1.	2.	3.	4.	5.
Moisture	4.86	4.34	2.57	1.99	3.79
Volatile matter	36.66	37.79	41.87	40.51	38.01
Fixed carbon	56.89	54.96	42.54	37.49	44.52
Ash	1.59	2.91	13.02	20.01	13.68
Total	100.00	100.00	100.00	100.00	100.00
Sulphur	0.67	0.76	0.92	2.04	1.09

These analyses show that the Palmyra coal in its best condition is one of the finest coals of the State, in no respect inferior to the best mines of the Mahoning Valley. The cannel seam of the Scott bank was carefully examined to see if any portions of it rated higher than the rest. It is poorest in the middle, but the top and bottom of the cannel are fairly good representatives of that variety of coal.

This completes the account of the coal output of Portage county. Formerly a little poor coal was mined about Atwater. It probably belonged to the Mercer horizon, but nothing is now done in this field. The clays of the horizon are extensively worked.

V. COAL MINES OF STARK COUNTY.

As in the case of the counties already treated, the geology of Stark county has been given with considerable detail in the excellent report of Newberry, in vol. III. The discussion of the Massillon coal in the report is particularly full and valuable. Aside from the correction of the general section, the present report will be mainly confined to the more recent developments of the coal seams of the county.

General Section.

As already shown, there is in Newberry's report a double use of the numbers 5 and 6 in the southeastern corner of the county (see p. 69), but this error applies to but a small territory, and by far the larger part of the county falls within the limits of a section in regard to which there is no dispute. The main elements of the geological scale of Stark county are as follows:

22. Mahoning sandstone, coarse and sometimes pebbly.
21. Upper Freeport coal, passing into Blackband ore at many points (No. 7 of Newberry).
20. Upper Freeport clay.
19. Upper Freeport limestone.
18. Upper Freeport shale and sandstone.
17. Lower Freeport coal (No. 6*a* of Newberry).
16. Lower Freeport limestone.
15. Lower Freeport sandstone, often pebbly and massive, and reddish in color.
14. Middle Kittanning coal (No. 6 of Newberry).

13. Middle Kittanning shale, containing kidneys of ore, and sometimes masses of fossiliferous limestone.
12. Lower Kittanning coal (No. 5 of Newberry).
11. Kittanning clay.
10. Putnam Hill limestone and ore.
9. Brookville coal (No. 4 of Newberry).
8. Tionesta coal.
7. Upper Mercer limestone and ore.
6. Upper Mercer coal (No. 3*a* of Newberry).
5. Lower Mercer limestone and ore.
4. Lower Mercer coal (No. 3 of Newberry).
3. Massillon sandstone.
2. Sharon shales.
1. Sharon coal (No. 1 of Newberry).

The discussion of the Massillon coal field will be reserved for a subsequent portion of this report.

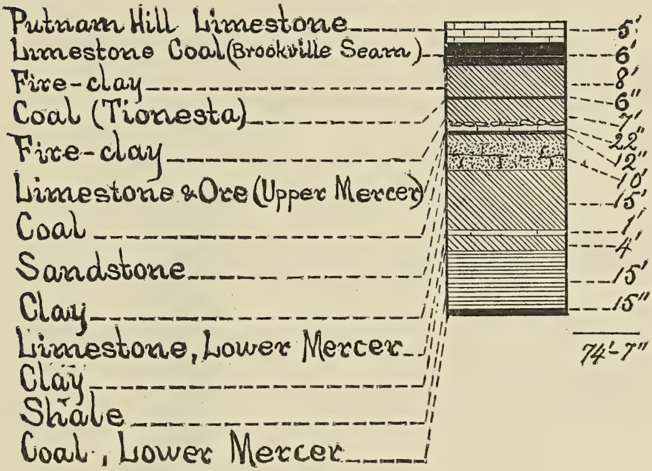
The coal supply of the county, aside from this important source, is chiefly confined to the following seams, viz., the Brookville or Upper Limestone coal, the Lower and Middle Kittanning, and the Upper Freeport coals. In addition there is one locality where the Tionesta coal yields a considerable supply. The Mercer coals both appear in their proper places in innumerable sections, but they nowhere attain workable thickness. A similar statement may be made as to the Lower Freeport coal.

The Brookville or Upper Limestone coal will be first described. It is Newberry's No. 4 for this region. It has been worked for a long time in Plain and Lake townships, and in the adjoining township of Green, Summit county, though heretofore in country banks only. In Canton and Pike townships, it has also been worked in a small way at a number of points for many years, but since the opening of the Valley Railway, four shipping mines have been developed in the seam, one at Greentown, one in Plain township, 3 miles north of Canton, and two mines in Pike township, at Fox Run and Evansdale, respectively. The seam is thus coming into the general market, and is now for the first fairly tested in its adaptations thereto.

The section at Greentown, including the coal, is as follows. It was obtained at Stripe's Clay Works, ½ mile below the station, and is represented in Fig. XXXVI:

FIGURE XXXVI.

SECTION AT GREENTOWN.



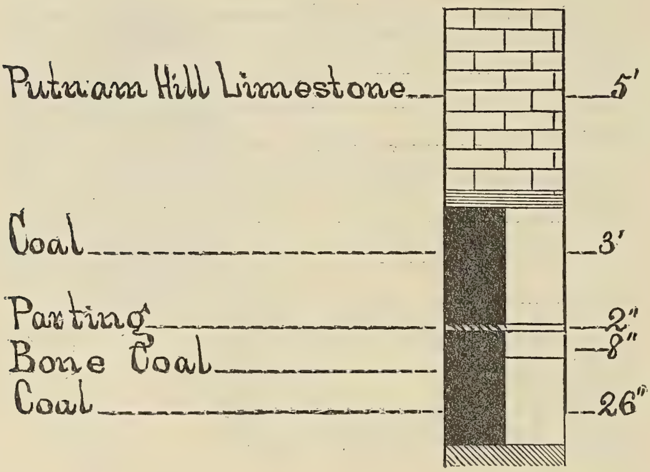
	Ft.	In.
Putnam Hill limestone	5	
Shale	0	4
Brookville coal (No. 4)	6	
Clay—Potters'	6	
Tionesta coal	0	6
Clay	7	
Upper Mercer limestone and ore	1	10
Upper Mercer coal	0	10
Sandstone	10	
Clay	15	
Lower Mercer limestone	1	
Clay—Potters'	4	
Clay—Sewer-pipe	12	
Lower Mercer coal	1	3

This section is an interesting and valuable one, inasmuch as it contains a clear showing of several of the best worked horizons of the Lower Coal Measures.

The structure of the Greentown coal is shown in the accompanying diagram, Fig. XXXVII.

The coal was opened at this place for a shipping bank by Smith, Borst & Co., under the name of the Greentown Coal Company, shortly after the Valley Railway was completed, and for a year or two, a con-

FIGURE XXXVII.
STRUCTURE OF LIMESTONE COAL AT GREENTOWN.



siderable amount of coal was mined, the monthly output reaching 150 cars, but the mine has now been closed for some months on account of litigation within the company. The coal was largely used as a steam coal by the railroad. It is undoubtedly better adapted to steam generation than to other uses.

The roof of the coal is the Putnam Hill limestone, between which and the seam a few inches of protecting shale intervene. The roof is very firm and strong, and is easily held in place.

The under clay is a plastic clay, quite white, and valuable for potters' use. It would make a troublesome bottom, probably, in mines worked on a large scale.

The seam is seen to be divided into two well-marked benches, an upper and a lower. Between them there is a marked difference in quality, the upper bench having in all respects a great advantage.

The upper bench is 3 feet thick, and is an open-burning, bright and well-jointed coal. It mines in fairly large blocks, but breaks easily, and therefore does not bear handling as well as many seams. It is said to yield a light colored ash, but the composition would lead us to expect a reddish ash. The ash is not excessive in amount, and this bench is not given to troublesome "clinker." Its average composition is shown in the following analysis:

Greentown coal, upper bench	*Lord.*
Moisture	3.71
Volatile matter	42.50
Fixed carbon	48.85
Ash	4.94
Total	100.00
Sulphur	3.73

The percentage of sulphur is large, but this is the only notable drawback.

Below the two-inch clay parting a layer of "bone coal" or lean cannel occurs. It has no place in the general market, but it is sometimes turned to a small account in local use.

The lower bench has at times an extra parting in the shape of a sulphur binder, about 1 foot from the bottom, and it generally contains many thin bands of mineral charcoal, charged with pyrites, which are known as "black sulphur." The lowermost foot of the seam is worse in this respect. From this structure it is apparent that the coal will mine small, and will prove a dirty seam. It yields an excessive amount of dark gray ash, and tends to form a troublesome clinker, or in the common phrase, to "run on the grate bars."

These facts put it at disadvantage as domestic fuel, but the product of both benches is said to give fair satisfaction as a steam coal.

The lower bench is counted richer in bitumen than the upper. It is certainly less open-burning in character. Its average composition is shown in the following analysis:

Greentown coal, lower bench	*Lord.*
Moisture	3.71
Volatile matter	40.53
Fixed carbon	42.09
Ash	12.79
Total	100.
Sulphur	5.74

The statements made above as to the character of this bench were derived from the testimony of those who had used it, but they will be seen to be borne out entirely by the results of analysis. The ash and sulphur together form 18.53 per cent. of the whole, and would necessarily produce the unfavorable results that have been noted.

If the upper bench were mined by itself, it could enter the market under fair conditions for competition. The "bearing in" could all be

done in the lower coal, and the upper bench could thus be worked to the greatest advantage. It is fully 3 feet thick, and a great deal of coal is now mined successfully in the State that does not exceed this measure. For roads and for undermining, the bottom bench would serve a useful purpose, and, no doubt, some market could be found for the small coal made.

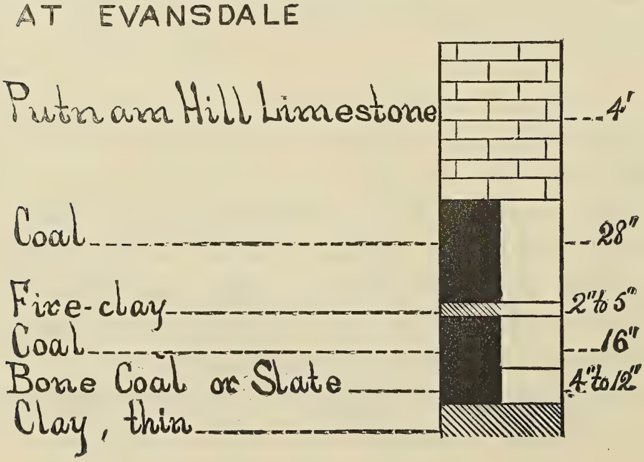
When worked as a whole, the seam yields 2 tons of lump coal to one of nut and one of slack, over a screen 7x5 feet, and with 1¼ inches between the bars. The coal mines easily. The royalty is 15 cents per ton of clean coal.

The next shipping mine in the seam is the Evans mine, 2½ miles north of Canton. The same general conditions prevail here.

Five miles below Canton, on the line of the Valley Road, two new mines have recently been opened in the same seam. They are known as the Fox Run and Evansdale mines, respectively. The latter has a very complete equipment for doing its work to advantage. The seam at this mine is 5 feet thick where measured, and the structure is as follows:

	Ft.	In.
Putnam Hill limestone	4	
Coal, upper bench	2	4
Fire-clay parting		4
Coal, lower bench	1	4
Bone coal or slate		4 to 12

FIGURE XXXVIII.
STRUCTURE OF LIMESTONE COAL AT EVANSDALE



The bearing in is done at the clay parting, and the benches are blasted separately. The average composition of the entire seam is as follows:

Evansdale coal	*Lord.*
Moisture	2.85
Volatile matter	39.00
Fixed carbon	46.69
Ash	11.46
Total	100.
Sulphur	3.14

The specific gravity of the coal is 1.33. The benches were not examined separately, but there is little reason to doubt that the facts reported for Greentown would in the main be applicable here. The Fox Run mine duplicates this description. The coal at these mines is a little harder than at Greentown, yielding three cars of lump to one of nut and one of slack.

The four mines now described constitute the only shipping banks in the State in the Brookville or Putnam Hill Limestone coal. The seam is at its best in the portions of Stark county, already referred to. The limits of the field which it occupies have not been traced with precision, but it is known to extend, though no doubt with occasional interruptions, from Greentown on the north to the valley of Big Sandy Creek. The proved breadth of the seam in this large volume is much less, but workable deposits are found at least four miles apart in an east and west line.

There are three other shipping mines along the line of the Valley Railway, between Canton and the Mineral Point district.

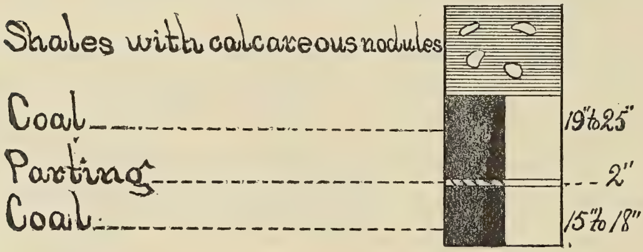
The first of them is a new bank just opened for the general market, though long worked in the small way for the neighborhood, and as a small element in the supply of Canton. The mine is situated a mile and a half northwest of North Industry. It is to be known as the Chestnut Grove mine of the Richards Coal Company of Canton.

The mine is opened in the Middle Kittanning seam, No. 6 of Newberry, in its northwestern extension for this region. It lies higher in the hills than any other mine in the county, though still holding good cover. There are 225–250 acres of the coal connected in one way or another with the mine. Royalty is 14 cents per ton of clean coal.

The seam has a good name in Canton. It is a smith coal, and has been used for tempering saws in the factory, displacing the Pittsburgh seam for this purpose. It is also highly approved as a domestic fuel. It will be brought into competition with Massillon coal, but not on quite equal terms, as the difference in royalty alone allows it to be sold at a lower rate by at least 20 to 40 cents per ton. As a steam coal it gives good satisfaction. It burns freely, and makes but little clinker.

The seam ranges in thickness from 3 to 4 feet, but it rests mainly at the smaller figure so far as now shown. The structure of the seam is as follows:

FIGURE XXXIX.
STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT CHESTNUT GROVE MINE AT NORTH INDUSTRY.



Upper bench	19 in. to 25 ft.
Parting	2 in.
Lower bench	15 to 18 in.

The coal from the lower bench is the purer. It is mainly made into small coal in mining, and on this account the nut coal of the mine will be more valuable than usual. The coal is bright and clean, and shows fair strength in handling. Over a screen, 1½ inches between the bars, there has been thus far made four cars of lump to one of nut coal, and a little less than one car of slack to the same lump coal. The slack is sold at a price that pays at least for handling. The coal mines easily, and little or no powder is required outside of entries. There are occa-

sional sulphur balls in the upper bench. The composition of the seam is shown in the following analysis:

Chestnut Grove coal, North Industry	*Lord.*
Moisture	4.82
Volatile matter	40.68
Fixed carbon	49.78
Ash	4.72
Total	100.
Sulphur	2.04

This result is in keeping with the other analyses of this seam in the vicinity, and shows a coal of good character.

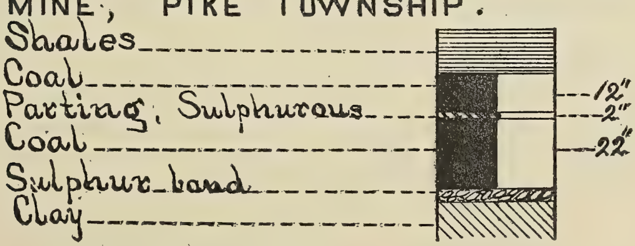
There are a few feet of shale always, and often 30 or 40 feet, over the coal. Large nodules of fossiliferous limestone sometimes are found next to the coal. The same thing often occurs in connection with this seam in Tuscarawas county. The shale makes a fair roof, but slakes in the entries when they are traversed by a full current of air.

The floor of the coal is a heavy bed of soft, plastic clay, which, by the action of the air, swells and throws the track, and otherwise causes some trouble.

Two miles below North Industry another small mine is found in the same seam. It is commonly known as the St. John mine, but it is now operated by the Harry Pocock Mining Company. The coal is 3 feet thick, and has a single parting, but the division comes higher in the seam than in the mine last described, being only about 14 inches below the top.

FIGURE XL

STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT THE POCOCK (ST. JOHN) MINE, PIKE TOWNSHIP.



A sulphur band lies in the bottom, and the parting is often little else.

The composition of the seam at this point is as follows:

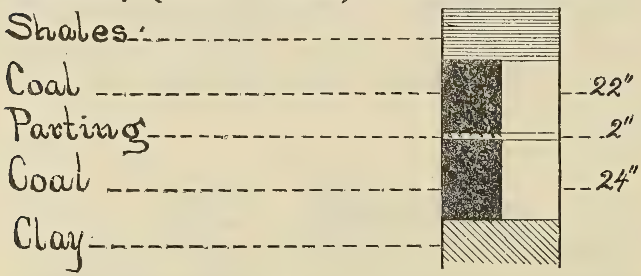
St. John coal, Pike township	*Lord.*
Moisture	4.44
Volatile matter	37.38
Fixed carbon	49.07
Ash	9.11
Total	100.00
Sulphur	4.69

These results are not as favorable as could be desired.

On the opposite side of the valley are the Willow Spring mines of the Ridgway Burton Company. Both this and the last-named mine are situated in Pike township. The coal worked here is the Lower Kittanning seam (Newberry's No. 5). The seam is 4 feet thick, and is divided into two equal benches by a 2-inch parting. Its structure is shown in the accompanying diagram:

FIGURE XLI

STRUCTURE OF LOWER KITTANNING COAL (No. 5) AT WILLOW SPRING MINE, (BURTONS) PIKE TOWNSHIP.



The character of the coal can be seen in the following analysis:

Willow Spring coal, Pike township	*Lord.*
Moisture	4.46
Volatile matter	42.42
Fixed carbon	48.84
Ash	4.28
Total	100.00
Sulphur	2.56

These figures show a good coal. They are decidedly above the average for this seam. The coal has heavy cover, and quite a large areao f it is tributary to the mine. Like the Richards mine, it also lies near the outer margin of the Kittanning horizon for this region.

Near Burton's Switch, and in connection with the mines now described, the following general section was obtained:

		Ft.	In.
1.	Buff limestone, Lower Freeport.		
2.	Sandrock and shale	50	
3.	Coal No. 6	3	
4.	Fire-clay, white and sandy	11	
5.	Shale with a few ore balls	28	
6.	Coal No. 5, 2 ft. 6 in. to 4 ft. 2 in	3	
7.	Interval, concealed	61	
8.	Putnam Hill limestone	4	
9.	Limestone coal, Brookville (No. 4)	5	
10.	Fire-clay	4	
11.	Shale and sandstone	6	
12.	Coal (No. 3*b*), Tionesta	1	4
13.	Shale	28	
14.	Limestone, Upper Mercer	1	6
15.	Coal No. 3*a*	1	
16.	Limestone (?)	1	
17.	Interval to bed of creek	15	

There is one other important field of the Middle Kittanning seam (No. 6) in Stark county. It is in Osnaburg township. The coal has been worked here in numerous small mines for many years, and a large part of the supply of Canton has hitherto been obtained from this source. Since the building of the Connotton Valley Railway, two shipping banks have been opened near the village of Osnaburg, and are now in operation. The coal from this neighborhood has an excellent name. A small part of the seam is highiy valued as smith coal, and is often sold separately for this purpose at advanced price. In general, the product of these mines commands a higher price in the neighboring towns and villages than the other coals that the railroads supply. The seam is 3 ft. 6 in. thick, and although the seam lies quite high, being 624 feet above Lake Erie, a large acreage is to be found here. The average composition of the whole seam is shown in the following analysis of the coal of the Osnaburg Coal Company:

Osnaburg coal	*Lord.*
Moisture	4.07
Volatile matter	41.13
Fixed carbon	49.50
Ash	5.30
Total	100.00
Sulphur	2.67

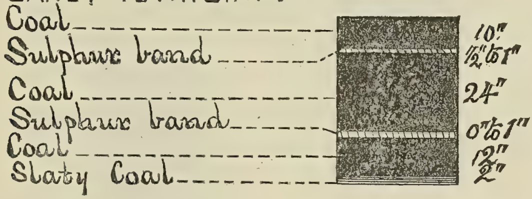
These figures show a close correspondence with those given for the same seam at North Industry, but they indicate a slightly lower quality. Such differences as these, however, can well enough be referred to the accidents of sampling, but the analysis given above can be taken as typical of the Middle Kittanning coal, from Stark county westward to the central portions of Perry county, where, as it will be remembered, the seam changes quite abruptly in chemical and physical character as well as in volume. The volatile matter slightly exceeds 40 per cent.; the fixed carbon always falls below 50 per cent.; the ash runs low, while the sulphur always exceeds 2 per cent., often occurring in double this amount.

This seam is also worked at many points in Paris township, holding its thickness and general characteristics. In Sandy township, and also in Rose and Brown townships of Carroll county, which adjoin it, and which, like it, are traversed by the Big Sandy Valley, the two Kittanning coals are everywhere present, the lower rising and falling in volume as usual, but the upper seam maintaining its remarkable steadiness. It is here known as the Four-foot seam or Upper seam, but it seldom rises much above 3 feet in thickness. The lower coal is commonly counted stronger as a heating coal, but it runs higher in sulphur. A few points will be noted in and adjacent to the valley, where these seams are now worked, and where their characteristics may be learned.

The Lower Kittanning coal has been worked for many years on the farm of W. Baum, in Sandy township, near the county line, about 3 miles north and east of Waynesburg. The coal has always been more highly esteemed than that of other mines accessible, and consequently mining is continued in it, although at considerable disadvantage. The mine is located in a valley, and the coal has but very light cover. A large part of this consists of the ordinary valley deposits of sand and gravel. There is really no roof to the mine, except what the miner

carries in. The seam exceeds 4 feet in thickness, and has the structure indicated below.

FIGURE XLII
STRUCTURE OF BAUM'S COAL
SANDY TOWNSHIP.



	Inches.
Coal	10
Sulphur band	1
Coal	24
Sulphur band	0–1
Coal	12
Slaty coal	2

The 12 inches of coal nearest the bottom is counted the best. Analysis shows that the high estimate placed on the seam is not without warrant. Its average composition is shown below:

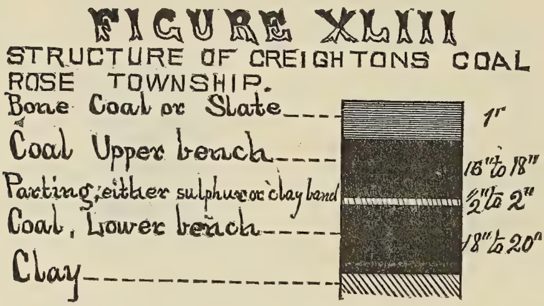
Baum's coal, Sandy township	*Lord.*
Moisture	3.20
Volatile matter	41.79
Fixed carbon	51.59
Ash	3.42
Total	100.00
Sulphur	1.93

These figures are exceptional, and show one of the best coals of the region. There is not reason to expect a large acreage of this volume and quality. On adjoining farms the seam is found but 18 inches thick. Still other basins like it are sure to reward future exploration.

The upper coal is well shown on the farm of Samuel Creighton, in Rose township, 2 miles southeast from Magnolia. A mine is opened in it here. Most of the openings in the neighborhood have been made on the dip of the coal, and so have shortly filled with water, and been

abandoned. This mine is opened against the dip, and though it lies so low that it has nothing to spare, it still drains itself.

The structure of the coal is as follows:



	Inches.
Bone coal or black slate	12
Coal, upper bench	16 to 18
Parting, sulphur band or clay band	½ to 2
Coal, bottom bench	18 to 20
Clay	———

The thickness of the seam here is 3 feet strong. The coal has its usual good quality.

The seam holds its way with even tenor as it is followed up the valley. Mining in it has nowhere been attempted, except in farmers' banks, and they are everywhere, but the seam is certain to come into demand, and at no distant day. Its steadiness, its quality, and its nearness to the margin of the field, are all points in its favor, and furnish a basis for successful mining that will not long be disregarded. It lies low in the hills, and thus occupies a wide area. Thinner seams are already successfully mined in the large way in Ohio, and steadiness is coming to be recognized in its true place as a very important element in such enterprises.

The Kittanning clay, underlying the Lower Kittanning coal, is an element of great value in the lower portion of the Big Sandy Valley, as will be shown elsewhere.

This field has nothing to stimulate speculative enterprises, as none of its elements have any unusual volume or value, but a safe basis for a prudent and permanent business is certainly furnished by it.

The Upper Freeport coal (No. 7 of Newberry in this field) has been named as one of the seams mined in Stark county. Its horizon is

one of great interest, but its contribution to the coal supply of the county is insignificant. Neither it nor the Lower Freeport seam has any real value as a coal horizon, though both have been found and worked in various localities.

The Upper Freeport coal, it will be remembered, bears the famous Blackband ore of this portion of the State. These deposits will be described by themselves, and only the coal that underlies them will receive attention at this point.

On the east side of Sandy township, near the county line, on David Stull's farm, the Upper Freeport coal has been found and worked to a small extent. The seam was here 3 feet and more. It was overlain by a heavy mass of bituminous shales carrying considerable iron. The shales were mined as Blackband, and were calcined on the ground, but were not found rich enough in iron to pay for working, and consequently were never removed from the kilns.

The same horizon is also reached on the east side of Osnaburg township, and also in Paris. Some extensive deposits of Blackband have been worked in the former. The coal has not been opened by itself in Osnaburg, but in Paris a few small banks have been worked at one time or another. None are now known to be in operation. The usual interval between the Middle Kittanning coal (No. 6 of the Tuscarawas Valley) and the Upper Freeport coal (No. 6 of the Yellow Creek Valley) is 120 to 140 feet in this region.

One other coal seam must be counted among the sources of supply of Stark county. It is a seam that is worked in scarcely any other portion of the State. It lies 10 to 15 feet above the Upper Mercer limestone, and 25 to 30 feet below the Putnam Hill limestone. It has been identified by its position with the Tionesta coal of the Pennsylvania Survey. The only portion of the county in which it is found of thickness sufficient to warrant working is in the southwestern corner of Pike township. The seam will be described among the Tuscarawas county coals, among which it is known as the Bolivar coal.

VI. COAL MINES OF CARROLL COUNTY.

(See Sketch Map on page 65.)

The coal seams of the Lower Measures, now worked in Carroll county, are the following:

Upper Freeport coal	{ No. 7 on the Tuscarawas, No. 6 on Yellow Creek and Beaver.	
Interval		30 to 60 feet.
Lower Freeport coal	{ No. 6*a* on the Tuscarawas, No. 5 on Yellow Creek, etc.	
Interval		70 to 100 feet.
Middle Kittanning coal	{ No. 6 on the Tuscarawas, No. 4 on Yellow Creek, etc.	
Interval		20 to 30 feet.
Lower Kittanning coal	{ No. 5 on the Tuscarawas, No. 3 on Yellow Creek, etc.	

The first of the list outweighs and overshadows all the rest so far that no great injustice would be done if all but this seam were omitted in our review.

The coals of the valley of Big Sandy have already been described under the preceding section. It is here that the only field of the county is found in which the Kittanning coals have any value. The statements previously made express the facts as to the quantity, quality, and conditions of these seams throughout those portions of Rose and Brown townships that are traversed by the valley. The same seams can be followed under like conditions up the Connotton Valley, but they barely enter Carroll county above drainage. The facts in this connection have already been given on pages 77 and 78 of chapter I, and no further statements in regard to these seams are called for here.

The Freeport horizon is co-extensive with the limits of the county. It lies high in the hills in Rose and Brown townships, and it is but occasionally reached, and then only in the deepest valleys, in Lee, Loudon and Perry townships, in the southeastern corner of the county, but there is the best of reason for believing that it extends through all of this region, even where it does not come to light in the valleys. This reason is found in the fact that as soon as the proper level is reached by following downwards any of these valleys, the series promptly appears. The place of the Freeport Group is also deeply

covered in parts of Harrison, Washington and Center townships, but its horizon is reached in other portions of these townships.

In Augusta, East and Fox townships there is a moderate development of the series, especially of the Upper Freeport coal. The coal as worked here is the extension of the Salineville field. It is on the edges of that basin, however, and is not only thinner than the coal of the Big Vein at Salineville, but it suffers much more frequent interruptions, long stretches of barren ground occurring between the small areas of productive coal. Only country banks are to be found throughout this portion of the county, except on the very eastern boundary of Fox, where the coal has been opened by the Salineville operators. It proved too thin for any large business here, scarcely exceeding 3 feet.

The Dell Roy Coal Field.

The one coal field of the county that has so far attained any importance as a mining center is that which is known as the Dell Roy or Sherrodsville field. It has recently been developed in connection with the building of the Connotton Valley Railroad, but at Leesburg, and also at Bowerston the same seam has long been worked to a considerable extent (see chapter I, pages 77–78–79).

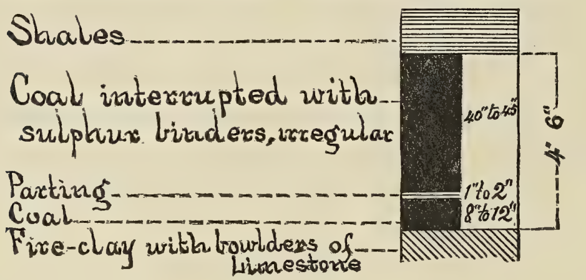
This field occupies the contiguous and connected portions of Center, Union, Monroe and Orange townships. It also extends into Monroe township of Harrison county. The coal seam on which its value depends is the Upper Freeport coal, and the field makes the second of the important basins of this seam so far found. The horizon of the coal extends beyond the boundaries named, it is true, but on the northern and western margins of this district in Brown and Rose townships, as also in Sandy and Fairfield townships, of Tuscarawas county, its chief interest and value are transferred to another element, viz., iron. It here supports the great Blackband deposits that have made the region famous.

The Dell Roy coal field may be counted as beginning in Center township, in the vicinity of Carrollton. One mile southwest of Carrollton a number of mines have long been in operation for the supply of the town and the adjoining country. They all lie a little above the Indian Fork of Connotton or its several tributaries, in the valleys of which they are reached.

Of these mines the Moody Bank is the largest and best known. The coal is 4½ feet thick, and the quality is up to the usual standard of the seam. The structure is shown in the following cut, Fig. XLIV:

FIGURE XLIV

STRUCTURE OF MOODY'S COAL.



An excellent section, embracing several other elements, is found at this point. It is as follows:

	Ft.	In.
White and blue shales, in railroad cut	10	
Coal—Brush Creek, Salineville Strip Vein	0	6
Fire-clay and shale	8	
Limestone and iron ore, in two beds	4	
Lower containing *Cythere* in beautiful condition.		
Shales	8	
Sandstone—Massive, Mahoning	21	
Shales	9	
Coal—Upper Freeport	4½	
Fire-clay	4	
Limestone—Upper Freeport, with *Spirorbis*	4	
Concealed	20 to 30	
Coal—Lower Freeport, found in well directly below the mine	2	2

The coal in the Moody mine is fairly steady, but in several of the adjoining banks it has run down in thickness, or has in places entirely disappeared. On the Atwell farm, its limestone shows in full force, but the coal is altogether wanting, so far as investigation has gone. Clay veins are common throughout these mines, but are less detrimental to the coal than they usually are.

Two miles below the Moody mine, Empire mine No. 1 on the Scott farm is reached.

The mine was opened and equipped for a large business. The coal was struck 6 feet thick in the drift, and it maintained this volume with

perfect regularity and steadiness for more than a hundred yards, when it was quite abruptly reduced, running down as low as 2 feet. The circumstances attending the purchase of the coal of this farm illustrate the unsteadiness and uncertainty of the seam. After the entry was fairly begun by the owner of the land, Wm. L. Scott, Esq., and the coal was found of excellent thickness and quality, a company proposed to buy the coal on the farm, but desired permission to test it further by driving the entry forward for a week. Permission was granted, and the coal maintained its character in all particulars. At the expiration of the week, three days more were asked and granted for continuing the test, and still the coal held its own in every respect. A second extension even was granted, and as the coal was found in full volume, and of the best quality, the bargain was closed. Within 24 hours thereafter the coal began to fail in the entry, and was soon reduced to 2 or 3 feet. So numerous were the irregularities and failures of the seam on the property that the mine was soon abandoned, and it stands idle to-day.

The Lower Freeport coal was found, 18 inches thick, 30 feet below the main seam in the excavations for the weigh-house.

The Brush Creek seam is found on the same farm, and has been worked to a small extent. It shows the following structure:

	Ft.	In.
Black shale with thin plates of iron ore	2	
Coal	0	4
Soot band, thin.		
Coal	2	2
Clay parting	0	1
Coal	0	6

The appearance of the coal is good. The interval between the Upper Freeport coal and this seam is about 50 feet through this region. It could not be measured at this particular point.

The mines of Samuel Allen & Son, and of the New York and Ohio Coal Company (Empire No. 3) are next found to the right of the railroad as we descend the Indian Fork of Connotton. The coal is here shown to good advantage.

Analysis of the product of these two mines shows the following composition:

Dell Roy coal, Empire No. 3	*Lord.*
Moisture	4.20
Volatile matter	37.01
Fixed carbon	51.64
Ash	7.15
Total	100.00
Sulphur	3.09

Some of the coal produced is considerably better than these figures would indicate, but in all essential particulars the analysis is characteristic of the seam. The ash is a little in excess of much of the output.

Clay veins make but little trouble with the seam at this point. The chief irregularity consists in what are termed *horsebacks,* which are due in all cases to a descent of the sandstone roof, by which the shales are first cut away, and after them the coal more or less seriously.

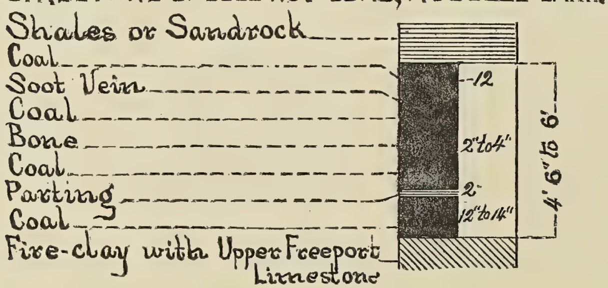
One of the last-named mines, viz., Empire No. 3, encountered a descent of the sandstone in recent workings, which extended for 60 yards, and which reduced the coal from 4 ft. 10 in. to 1 ft. 6 in., but the seam regained its full thickness beyond. This channel held a direction of S. 15° E. Mr. Andrew Lee, Superintendent of the New York and Ohio Coal Company's mines, has found this to be the general direction of the sandstone troughs wherever they occur in this part of the field.

The coal of the Allen mine is one of the most regular and valuable bodies of the Dell Roy field.

Around the village of Dell Roy the Upper Freeport seam has long been worked for local supply, and numerous drift entries still exist here. Just beyond the town, Russell and Wetzel have recently opened a small mine, in which the coal showed the following structure:

FIGURE XLV

STRUCTURE OF DELL ROY COAL, RUSSELL BANK.



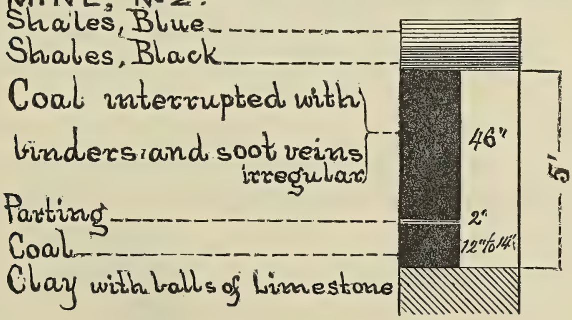
The coal was opened on the dip, and consequently the mine was troubled with water from the first. Water cannot be left in the clay floor of the coal without causing it to slack and throw the track, and interfere with the drainage. The bottom bench is generally counted the best portion of the seam, but there are no facts of analysis to establish this view.

The same structure characterizes the seam in the Empire mine, No. 2, which has an expensive plant, one-half mile south of Dell Roy. A greater thickness of coal than that last reported is, however, found at this mine. In the main entry a noble body of coal, fully 6 feet in thickness, is shown for a short distance, but there is also shown here one of the rapid and disastrous reductions of the coal, which unfortunately constitute a characteristic feature of the seam in all its extent. The seam in this field always gives way in the upper benches when its thickness is suddenly reduced, the bottom bench seldom being at all affected. The average thickness of the coal in the Empire mine, No. 2, was 4 ft. 10 in. in the rooms where it was worked, but it is counted a 5-feet seam. Horsebacks were so often met, and were of such large extent, that mining was suspended here for a time. It has, however, been resumed, and is to be carried forward on a large scale.

The general structure of the seam is shown in the following figure:

FIGURE XLVI

STRUCTURE OF DELL ROY COAL, EMPIRE MINE, No. 2.



The disappointment arising from the unsteadiness of the coal, when this latter fact is first discovered by the operator, often leads to a temporary undervaluing of the seam, but the fact remains that in spite of its frequent "wants," the Upper Freeport coal is still one of the most valuable seams of the State.

The composition of the coal of mine No. 2 is shown in the following analyses:

Dell Roy coal, Empire No. 2..*Lord.*

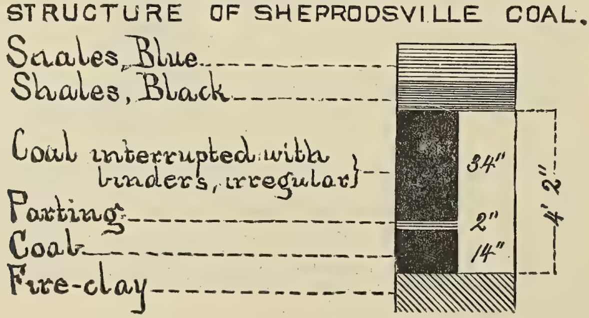
	1.	2.	3.
Moisture..	3.81	3.69	3.95
Volatile matter..	36.27	38.13	35.12
Fixed carbon	55.02	52.75	52.67
Ash	4.90	5.43	8.26
Total	100.	100.	100.
Sulphur	1.57	2.87	1.62

The first analysis is derived from the coal of the entire seam, as shown in a room. The second ıesult was got from sampling the loaded railroad cars. The third analysis was of a single block selected as the best of the seam (see page 148).

Between Dell Roy and Sherrodsville there are numerous country banks, in all of which the coal is found in good quality and good thickness. Among them may be named the banks of Pearch, Tholy and Yant. All hold the seam in fair volume, but best of all, they indicate the wide extent of the general field.

At Sherrodsville the seam is a little lighter in volume, but this loss is more than compensated in an increased steadiness. The coal runs about 4 feet in thickness. Its structure is shown in the following diagram:

FIGURE XLVII
STRUCTURE OF SHEPRODSVILLE COAL.



The composition of the coal is indicated in the following analysis:

Sherrodsville coal	*Lord.*
Moisture	4.20
Volatile matter	39.32
Fixed carbon	52.58
Ash	3.90
Total	100.00
Sulphur	1.92

These results show an excellent coal, as far as chemical composition is concerned.

In physical characters the coal agrees fully with the seam, as already described. It is a bright, clean, well-faced coal. The arrangement of the joints, as shown on page 144, causes it to mine in oblong blocks, the greatest length of which is generally about 2 feet, this fact being determined by the intersection of the end-joints or cutters, and the thickness of which varies from 8 to 10 inches. This structure is a marked characteristic of the seam. The coal is *long grained,* in one sense of this term.

The coal is soft or tender, and makes a large amount of nut and slack in the processes of mining and transportation. Three grades are made and sold, viz., lump, nut and mixed. The nut coal includes all that passes through a screen, $1\frac{1}{4}$ inches between the bars, 9 to 11 feet in length, and set at an angle of 28°. The mixed coal is what passes over a screen with a mesh of $\frac{5}{8}$ inch. When this grade has paid the expenses of handling, it has done about all that is expected of it.

At Sherrodsville a little less than two-thirds of what is sent out in the bank cars (65 per cent.) is lump coal. The balance is thus divided, viz., 13 per cent. nut, and 22 per cent. mixed. The Dell Roy figures vary a little from this, this coal being a trifle harder, and only 28 per cent. going through the first screen.

When the mixed coal is washed, it loses 5 per cent., and yields a good quality of pea coal. Experiments have been made in coking the washed product, which give good promise.

The normal roof of the seam consists of 2 feet of "soapstone," or soft blue shale, over which a foot of dark slate occurs, and above this the Mahoning sandstone, generally in massive proportions, is found. This makes a troublesome, but scarcely a dangerous roof. In working

the coal the shale soon falls in the main entries, leaving the sandstone for the permanent roof.

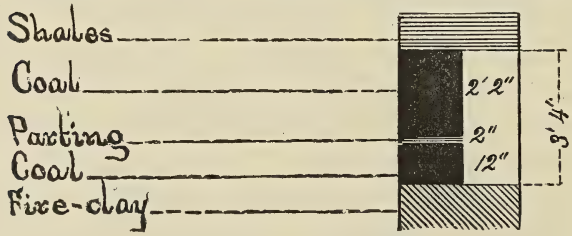
Rooms are generally worked 20 feet wide, and pillars are left 10 feet thick. The aim of the system now in force in the mines is to bring all the coal back.

The average daily output of a miner is 3 to 4 tons. The mines of the district have a large capacity, but they are now producing only 15,000 to 20,000 tons per month.

The coal maintains the traditions of the seam in being confined almost exclusively to the production of steam. It finds its chief market on the steamers of Lake Erie.

Sherrodsville is the furthest point to the southward at which a shipping mine occurs in this seam, but the coal holds with good volume and full value as far south as Bowerston, at least, and the line of the Pan Handle Railway. At Leesburg there is a mine that has been worked for many years, and the coal furnished by it has an unusually good reputation through the surrounding country. There is no good ground for questioning the identity of the Leesburg and Sherrodsville coals. At Bowerston, also, the coal has long been worked. It is now mined on a small scale by James C. Messenger. The structure of the seam at this point is shown below, the coal having a thickness of 3 ft. 4 in. to 3 ft. 6 in.:

FIGURE XLVIII
STRUCTURE OF BOWERSTON COAL.

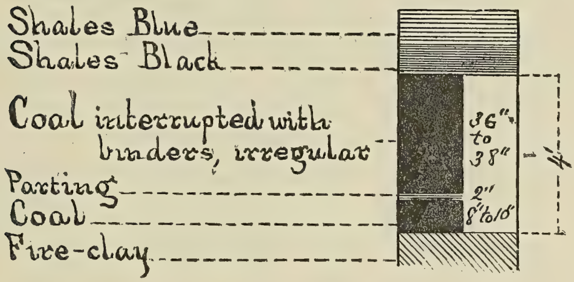


The seam can be traced westward along the line of the railroad with ease and certainty. At Wyandt's Bank, and in that vicinity, 3 miles west of Bowerston, it is shipped in the small way. Its structure here is shown in the following diagram:

FIGURE XLIX

STRUCTURE OF WYANDT'S COAL.

NEAR TUNNEL



Followed a little further westward, it comes into the same section again with the Middle Kittanning coal, which is there known as the Dennison or Pike Run coal. Its place is more than one hundred feet above this last-named seam.

The seam is also found in fair development to the west of Sherrodsville, on Thompson's Run. It has long been worked here in farmers' banks.

The several diagrams given, illustrative of the structure of the seam, are seen to agree in general character, and they help to establish the fact that all the mines named belong to a common horizon.

Returning to the Dell Roy field, a few statements are required as to the Lower Freeport coal. This is often a workable seam throughout this territory. Like the Upper Freeport coal it is unsteady, but it is found in a large number of the sections in which the former occurs. It does not rise beyond 3 feet in thickness, as a rule, and its quality is not equal to the upper coal.

It has been opened in a small way on the C. Smith farm, a mile south of Dell Roy. The coal is here 4 feet in thickness. It has also been opened by Dr. Sherrod, just above Sherrodsville, where it lies 51 feet below the Upper Freeport seam, and 12 feet above the level of Connotton Creek. Two feet of black shale immediately cover the seam. The coal is about 3 feet thick, and is underlain with a clay, carrying yellow nodules of worthless ore. The interval between the Freeport coal is sometimes reduced to 27 feet.

The southward dip of the series carries this seam below drainage soon after leaving this point, in ascending the Connotton Valley, but

there is no reason to doubt that it is the Lower Freeport coal which has furnished what basis there is for the traditions of an important coal seam at no great depth at Bowerston and in that vicinity. This is the seam that is reported in the recent drilling done for W. P. Penn, at Bowerston. The drillers testify to finding from 5 ft. 2 in. to 5 ft. 6 in. of coal about 70 feet below the Upper Freeport seam. Without calling in question their good faith, it seems safe to conclude that the interval is not as great as was reported, the measure being taken from the rope used in drilling, which is an unreliable mode of measurement at best. Furthermore, it is possible that the two feet or more of the black shale, that commonly overlies the Lower Freeport seam in this vicinity, may have been counted as coal. Such errors are known to be of common occurrence. Without discrediting these reports, therefore, and yet without accepting them as exact statements of the facts, it may be counted probable that a good seam of Lower Freeport coal, 3 feet or more in thickness, can be got by shafting between 50 and 60 feet below the Upper Freeport seam at Bowerston. It is well to remember in this connection that the Lower Freeport coal is the Shaft seam of Steubenville, and that this last-named seam ought to be rising to day at just this point. There is no reason to believe from any of the facts relating to this seam in its nearest outcrops, that it anywhere acquires great volume, and the prevalent belief to that effect in this vicinity is to be referred to the exaggerations that fasten themselves so commonly and so persistently to the records of drill holes, and other lines of facts that are incapable of verification.

The Brush Creek coal (Salineville Strip Vein) is fairly developed throughout this district. It is mined in the small way at many points, but it is nowhere shipped to the general market.

Other well-known elements that belong to higher horizons are, of course, found in the highlands of the county. Two sections will be here reported to show the range of intervals that is to be expected in this region.

The first is found in what is called the "Backbone road" from Bowerston to Carrollton, where it leaves the valley of Connotton, half-way between Smith's Mills and Sherrodsville. The lower intervals are normal here, but the upper ones are the shortest to be found in this district. The section is as follows:

	Ft.
Pittsburgh limestone, containing Spirorbis	15
Red shale	20
Sandy shales	45
Coal blossom.	
Shales	25
Crinoidal limestone	4
Blue shale } Brown shale } Black shale } Dark shale }	124
Nodular ore	1
Shale	5
Brush Creek coal, mined	4
Shale and not seen	30
Mahoning sandstone, seen	10
Shales	5
Upper Freeport coal	4
" fire-clay	6
" limestone	1
Not seen	40
Black shale	2
Lower Freeport coal	3
Fire-clay and nodular ore, and concealed	12
Level of Connotton Creek.	

The chief anomaly is in the measurement of 124 feet between the Brush Creek coal and the Crinoidal limestone. This is nearly 75 feet short of what is expected and found between these elements elsewhere.

The second section is found at and near Tunnel No. 10, on the Pittsburgh, Cincinnati and St. Louis Railroad. It is as follows:

Crinoidal limestone (coal blossom 44 feet below limestone)	5
Shales and concealed	120
Conglomerate ore and limestone, Cambridge limestone horizon (?)	10
Concealed	40
Thin-bedded sandstone	25
Brush Creek coal, blossom	—
Fire-clay	2
Brush Creek limestone	1
Shale	30
Sandstone	20
Shale	20
Upper Freeport coal, mined on Bell's farm	4
" clay	3
" limestone	1
Concealed	53
Lower Freeport coal, formerly mined on Clark's farm on railroad.	

The normal measures reappear here, though the points at which the two sections are taken are but a few miles apart. A number of these last-mentioned facts belong to Monroe township, Harrison county.

This brief review has been made to cover the present development of the Lower Coal Measures of Carroll county, including also the statements necessary as to the Brush Creek coal. This does not include quite all the coal seams of the county, as one of the Barren Measure seams is worked to a small extent in several townships, but principally in Lee. It is known as the Harlem coal. It is found about 40 feet below the Crinoidal limestone. It is of good quality, but its small volume precludes the present possibility of its being made a basis of large work. The Pittsburgh coal comes into the county, so far as known, only as a "blossom" on the highest hills.

VII. COAL MINES OF TUSCARAWAS COUNTY.

The type section of Tuscarawas county is to be found in the actual sections already reported in Figures XIX and XX. All of the workable coals of the county are shown here in their relations to each other.

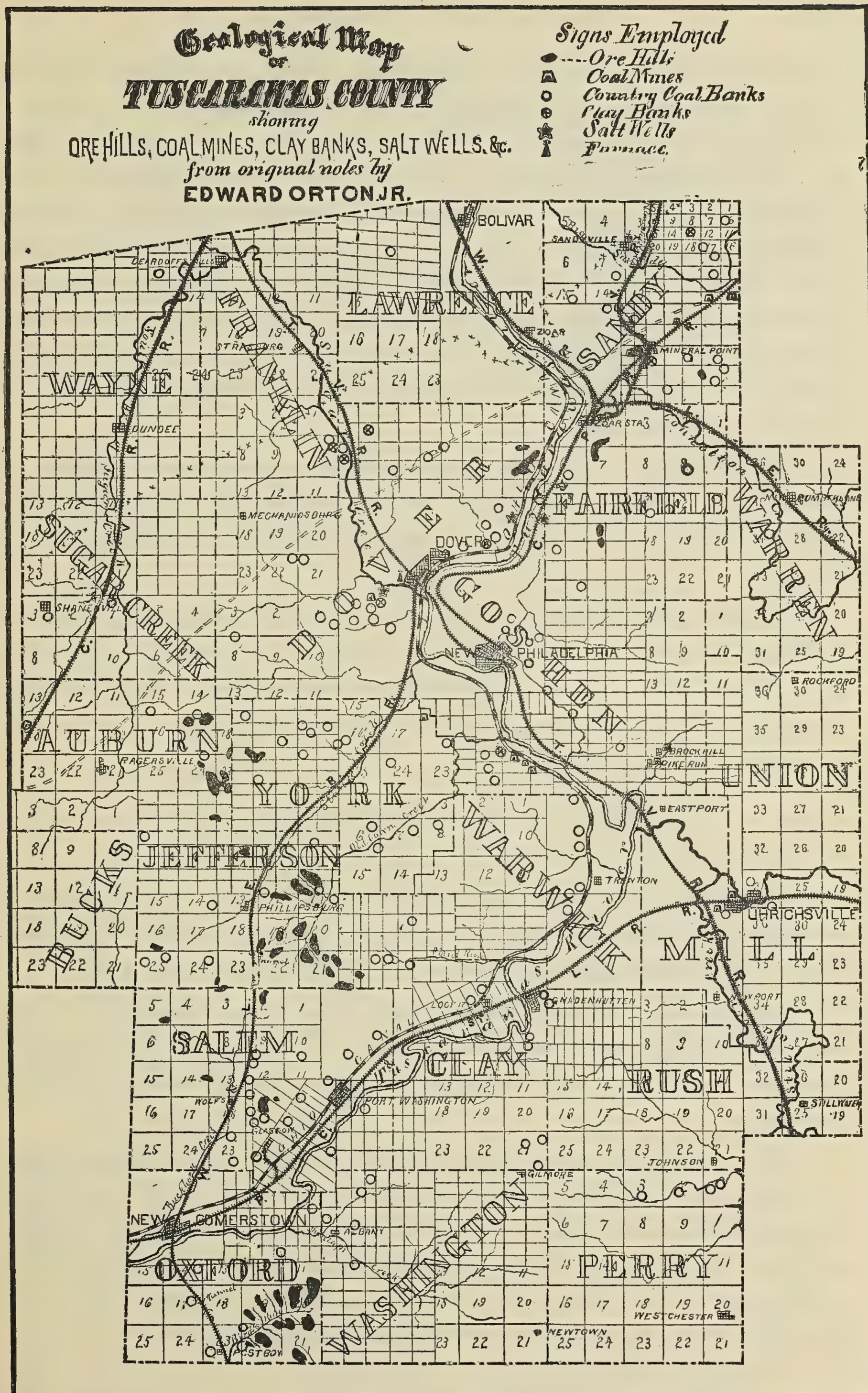
There are six separate and distinct seams of coal that are mined in the county, but there are only two that attain any considerable value as sources of fuel, and in fact a single seam far outweighs all the rest combined.

The seams that are mined in the county are the following, viz.:

Upper Freeport coal.
Lower Freeport coal.
Middle Kittanning coal.
Lower Kittanning coal.
Brookville coal.
Tionesta coal.

Openings are frequently made to the Mercer coals, but these seams add little to the fuel supply of the few districts in which they are found, so far as is now known.

Of the coal seams that are worked, the Middle Kittanning (No. 6 of Newberry) is by far the most important. The large mines of the


Geological Map of TUSCARAWAS COUNTY
showing
ORE HILLS, COAL MINES, CLAY BANKS, SALT WELLS, &c.
from original notes by
EDWARD ORTON JR.
Signs Employed
Ore Hills
Coal Mines
Country Coal Banks
Clay Banks
Salt Wells
Furnace.
LAWRENCE
SANDY
WAYNE
FRANKLIN
SUGAR CREEK
DOVER
FAIRFIELD
WARREN
GOSHEN
AUBURN
YORK
UNION
JEFFERSON
WARWICK
BUCKS
MILL
SALEM
CLAY
RUSH
OXFORD
WASHINGTON
PERRY
BOLIVAR
ZOAR
MINERAL POINT
DUNDEE
STRASBURG
MECHANICSBURG
DOVER
NEW PHILADELPHIA
SHANESVILLE
RAGERSVILLE
ROCKFORD
BROCKRILL
EASTPORT
TRENTON
PHILLIPSBURG
UHRICHSVILLE
GNADENHUTTEN
PORT WASHINGTON
GILMORE
JOHNSON
NEWCOMERSTOWN
ALBANY
WESTCHESTER
NEWTOWN
STILLWATER

county are all established in this seam. The Lower Kittanning coal (No. 5 of Newberry) is next in value. It is mined for the market in two townships, and is worked besides in numerous country banks. There are also important deposits of fire-clay and iron ore included in the Kittanning series, which are extensively worked within the county. Neither of the Freeport coals are shipped from within the county limits at the present time, though at several points each is found of mineable thickness. The Upper Freeport horizon holds, however, quite as conspicuous a place, and quite as great economic value as the best development of its coal could give to it, for it is the famous blackband iron ore horizon of the county.

In addition to the economic elements already noted, there are several salt wells in the county that derive their brine from the Berea Grit of the Sub-carboniferous formation, which is quite deeply buried here.

All of these elements, coal mines, ore beds and salt wells are indicated in the accompanying sketch map of the county. The most interesting feature of the map is the careful location of the blackband deposits of the county, as far as they are now known.

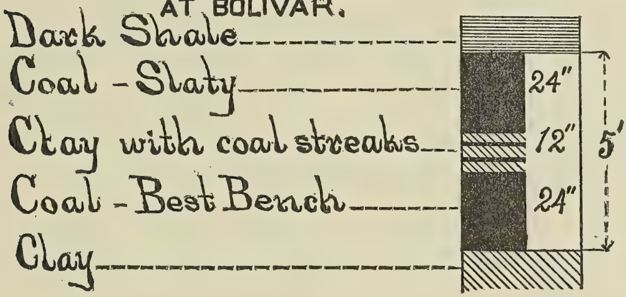
The Tionesta Coal (Coal No. 3*b*).

The coal seam identified as the Tionesta coal is confined in its valuable development to Lawrence, and possibly Franklin, Wayne and Sugar Creek townships. Even here it is of no great importance.

The position of the seam is from 10 to 15 feet above the Upper Mercer limestone, and about 35 feet below the Putnam Hill limestone. Its place and relations are well shown in the Bolivar section, recorded on page 67.

The coal maintains a good thickness through several square miles of territory to the west and south of Bolivar, and it is accordingly known as the Bolivar coal. It has been worked on a number of farms, viz., on the Belknap, Zutavern, and Baker farms. At present it is mined only on the last, and here in a small and inefficient way. The structure of the seam is shown in the subjoined diagram:

FIGURE L.
STRUCTURE OF TIONESTA COAL, (3b)
AT BOLIVAR.



The volume of the coal is good, but its quality is poor, as indicated by the following analysis:

Bolivar coal	*Lord.*
Moisture	2.94
Volatile matter	41.40
Fixed carbon	42.94
Ash	12.72
Total	100.00
Sulphur	3.30

The coal is short grained or curly. It is not easily mined, and the middle slate makes it very dirty. It is used only because of its accessibility, and it cannot hold its place where other coals compete on anything like equal terms. It is to be noted that the Baker bank is the only one in Northern Ohio in which this seam is at present worked. The seam is shown in many sections, but it attains its greatest thickness here. In Sugar Creek township it has been mined in years past, but is no longer worked.

The Brookville Coal (Coal No. 4 of Newberry).

The Brookville coal is worked at several points in the county in connection with its overlying limestone. The best development occurs in Dover township. The section found on the farm of William Swaby, in lot 30, has been already given (see Fig. XIX, B.). This section is prodigal in the display of the mineral wealth that belongs to this portion of the series. It contains two coal seams, two limestones, two horizons of iron ore, and two of fire-clay, that are all worked at the

present time. In addition, there are minor deposits of ore and coal that are shown in the section.

The Lower Mercer limestone is in strong force and of excellent character here. It measures 6 feet in thickness. It is mined quite largely for the Dover Furnace. The Gray or Putnam Hill limestone is 3 feet thick, and it also is of good quality, and is used for furnace flux. The coal which immediately underlies the limestone is better here than in most localities. It is $3\frac{1}{2}$ feet thick. It is divided into two equal benches by a clay parting, 6 inches in thickness. Contrary to what is found in Stark county, the bottom bench has the best reputation, and is used as a blacksmithing coal. The clay that underlies it is also worked for the market, and the three elements combine to invest the horizon with conspicuous interest. The coal would not be largely worked by itself, as it would not be able to compete successfully with the Kittanning coals, with which the district is so well supplied, but coming, as it does, as a secondary product, it is furnished at low rates, though, of course, in but small quantity. The Brookville seam is also worked at a few other points in the township under the same general conditions.

The Lower Kittanning Coal (No. 5).

This well-known and widely distributed seam (No. 5 of Newberry) occupies a considerable area in Tuscarawas county. Its most conspicuous development is in Sandy township, in the northeastern corner of the county. It has been worked here for a number of years in connection with its underlying clay, on the large scale. The last-named element here assumes its highest quality, and gives the name by which the Kittanning clay is best known in Northern Ohio, viz., the Mineral Point clay. The horizon of the coal is still further marked by the occurrence of a valuable bed of kidney ore that lies in the shales above the coal. The ore has been worked extensively for the Massillon and Canal Dover furnaces under the name of Shell ore. This stratum belongs rather with the small seam of coal, "the 18-inch vein," that lies 15 to 18 feet above the Lower Kittanning seam, but it is commonly associated with the latter.

The coal seam under consideration is worked in almost all portions of the township, but it is only at Mineral Point and in its immediate vicinity that facilities exist for shipping. The only mines of the town-

ship deserving of the name in this seam are the two mines, operated by C. E. Holden, at Mineral Point, the Welsh mine, the Tunnel mine, and the lately opened Wolf mine.

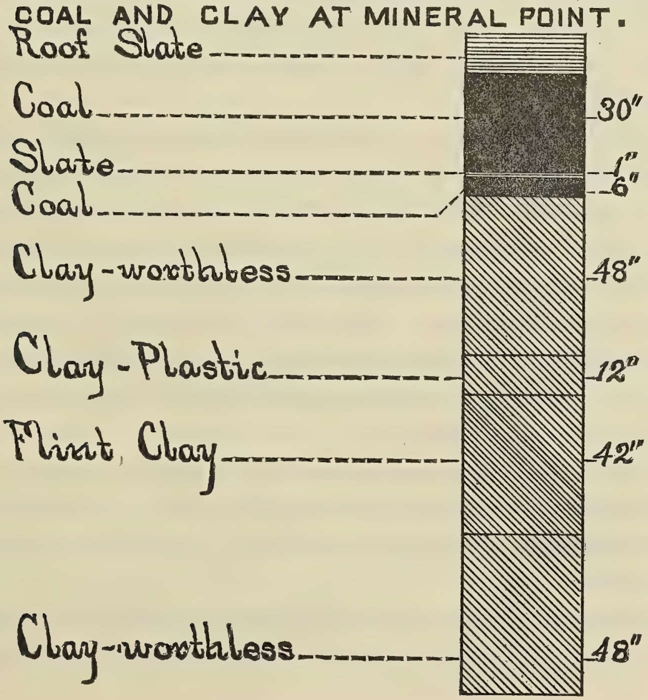
The country banks are numerous. The following list includes most of them:

S. Stall	On Zoar road.
— Birk	S. W. ¼, lot 3.
C. Bierly	S. W. ¼, lot 5.
Patrick Meagher	S. E. ¼, lot 9.
George Lechner	Lot 13.
Samuel Dolvin	Lot 16.
M. Dorringer	Lot 12.
Joshua Weaver	N. E. ¼, lot 7.
Henry Weaver	Lot 16.
Simon Rice	N. E. ¼, lot 12.
L. Summers	N. E. ¼, lot 15.
S. C. Diver	Lot 13.

The coal ranges from 2 ft. 6 in. to 5 ft., holding a thickness of 3 to 4 feet through a considerable area. Its structure at Mineral Point

FIGURE LI

SECTION SHOWING LOWER KITTANNING COAL AND CLAY AT MINERAL POINT.



is shown in the preceding diagram. The divisions of the clay that underlies the coal, and which far exceeds the latter in value, are also indicated.

The composition of the coal can be learned from the following analyses of Professor Lord:

No. 1. Holden's new mine, at Mineral Point.
No. 2. Tuscarawas Coal and Iron Company, tunnel mine.

	No. 1.	No. 2.
Moisture	4.26	3.35
Volatile matter	41.61	42.14
Fixed carbon	48.03	43.73
Ash	6.10	10.78
	100.00	100.00
Sulphur	2.28	4.77

The coal has a bright resinous luster, and well defined joints or cleavage planes. It mines fairly large, but it is tender and does not bear handling well. The lower and permanent parting is a pyritous slate. There is also visible pyrites distributed through the seam, often in large amount.

The floor of the coal, as shown in the foregoing figure, consists of 5 feet of plastic clay, below which the valuable deposit of the hard or flint clay is reached. This upper clay makes great trouble in mining on account of its expansion in the process of slacking. It more than doubles its volume as it slacks, and thus necessitates a great amount of work in keeping entries open. Sometimes the floors of the entries need to be cut down many times before they are given up. When any worked portions of the mine are left for a few months, they are practically closed by this rise of the floor.

The roof of the coal generally consists of shales, the entire interval between this seam and the Middle Kittanning that overlies it generally having this constitution. It gives way easily, and needs constant watchfulness and care.

The accidents of the seam in this district affect the mining of it almost as much as its essential characteristics. There is no known por-

tion of the coal field of Ohio where there has been a tithe of the disturbance that occurs in the vicinity of Mineral Point. The disturbance is shown in its most marked phases in a cut of the Valley Railway, a mile above Mineral Point. The rocks of the Kittanning Group, and a part of the Freeport Group are here found in a synclinal fold, the structure of which is complex. There is a northwesterly dip of 60° to 75° in part of the series. The Lower Freeport coal and limestone are shown in the railroad cut, as well as the Middle Kittanning, No. 6, the former being 18 inches thick. The Upper Freeport coal does not appear, but a coarse sandstone, apparently the Mahoning, is shown in the upper portion of the section, lying horizontal and unconformable on the edges of the upturned series. This fact fixes the date of the disturbance, if the reference of the sandstone is correct. In any case it brings out clearly the fact, not hitherto recognized in Ohio geology, that a considerable disturbance occurred near the end of the Lower Coal Measure period in this portion of the State.

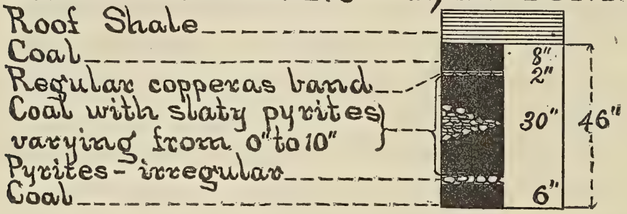
The results of this movement affect quite seriously all mining operations in this field. The disturbance is shown in Holden's old mine, at Mineral Point, in "clay veins" without number, in rolls and breaks in the coal, and sometimes in a doubling of the coal seam for a short distance. The coal has been found to rise at an angle of 45° in the mine, and to pitch downwards after a short distance at an equal angle. In short, there is not another mine in the State that makes any near approach to such irregularity as is shown here. The seam throughout this field is more or less involved, but the trouble seems to have culminated in the vicinity of Mineral Point.

The seam is not opened in Lawrence township to any extent, but there is proof of its presence there at some points in fair development. Its horizon is reached in Fairfield in several of the valleys, but the coal has not been reported here. In Dover township it is again quite largely worked, and the characteristics already given for the seam will apply without change to this locality. It is cut by many "clay veins," and every mine in it meets with more or less trouble, but still it is a basis for quite extensive work. The largest amount of coal has been taken from what is known as the Bodey or Wilhelmi Bank, opposite Canal Dover. The structure of the seam is shown in the accompanying figure. The deposit of pyritous slate represented in it is abnormal, and is only

found in one or two portions of the mine. In Jefferson township there are one or two small banks opened in the seam.

FIGURE LII

STRUCTURE OF BODEY'S COAL, CANAL DOVER.



The "clay veins" or "clay slips," as they are sometimes called, above referred to, constitute the most serious difficulty in the miner's work in this bank. When he fires a shot at night, he is never certain that a half foot or more of clay will not be disclosed between him and his next day's work. The Bodey coal ranges from 3 ft. 6 in. to 4 ft. 5 in. in thickness. Its quality is as good as is anywhere found in this seam.

John Hinkle mines the same seam in the same neighborhood. His coal averages 3 ft. 4 in. The coal of both banks is used for domestic supply in Canal Dover, for steam in the mills and factories of the town, and for salt boiling. It is also mined in the township by Henry Vogt, F. Lind, and Wm. Swaby. Lind's mine takes both clay and coal, and the Swaby farm yields a greater variety of minerals than any other one tract in the county.

This seam has assumed but little importance so far in any other portions of the county. It is often wanting in the scale, particularly in the western townships, and when present it is generally too thin to be worked to advantage. In York township a fine body of coal is probably to be referred to it, viz., the mine worked by Nicholas Winkler. This coal is 5 feet thick, has a waxy, resinous luster, and burns with a white ash. It is shipped to a small extent on the Wheeling and Lake Erie Railroad. It has an excellent name in the neighborhoods where it is known.

The Middle Kittanning Coal (No. 6).

The seam now to be treated, so largely preponderates in the coal production of Tuscarawas county that, aside from the mines already

described, but little injustice would be done if the entire production were referred to it. It is mined in every township of the county but one, viz., Perry, and it is quite probable that it underlies this town to a greater or less extent. It is or has been mined on the large scale in Goshen, Warwick, Mill and Union. In the Pike Run district of Goshen township, it supports two of the largest mines of the State. In Sandy, Dover, Fairfield, Salem and Oxford townships, though not worked in mines of great individual importance, the aggregate production of the seam is considerable. In the remaining townships it is almost the sole fuel supply of the people.

In Wayne, Franklin and Lawrence townships it occupies but little territory, as it lies high in the caps of their southern hills. Here, also, the seam shows the smallest volume. It does not generally exceed 3 feet in thickness in these towns, and the same measure is found in a large part of Dover. Indeed in most of the townships there are considerable areas in which it is a three-feet seam, though it often gains a few inches on this measure. It attains its maximum in Goshen, Warwick, Mill and Union, ranging here from 3½ to 5 feet in thickness, and the quality is also highest here.

The remarkable persistency and steadiness of the seam is nowhere better shown than in this county.

It has also as wide an outcrop here as in any other portion of the field, the proved breadth of the coal swamp being nearly 25 miles, measured from the western outcrop, southeastward on the line of dip.

The following sections and statements show the structure and general condition of the coal in a number of the townships of the county. The sections were taken from the worked mines and banks, and they naturally exhibit, therefore, the best development of the seam, as thus far found.

In Sandy township this coal is worked by J. A. Saxton, near Sandyville, the seam being 42 inches thick. John Black works it on his farm where it is 4 feet thick. It is also worked on Wm. Rice's farm, on section 13, where it is 42 inches thick. The Zoar Community has one mine in this seam, the thickness being 3 feet.

In Dover township the coal is worked in a small way by the following parties, viz.:

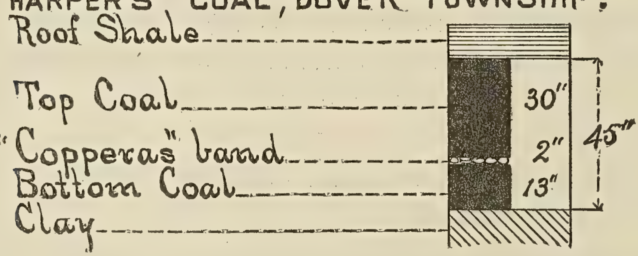
D. Knisely,
F. Rosenberg,
Jas. Harper,
P. Stockdale,
S. Rhinehart,
Geo. Weber,
Kurtz and Weber,
Harvey Gibbs,
A. Snyder,
Isaac Crisman,
D. G. Hill & Co., Dover Salt Well.

The coal is 4 feet thick near the river, but runs down in thickness as it is followed northward. Geo. Weber's coal is 32 inches thick. Kurtz and Weber have 36 inches. The lowest thickness of the other banks is 42 inches. The average is 46 inches. Several banks carry 4 feet quite regularly.

The structure of Jas. Harper's coal is shown in the following diagram:

FIGURE LIII

HARPER'S COAL, DOVER TOWNSHIP.

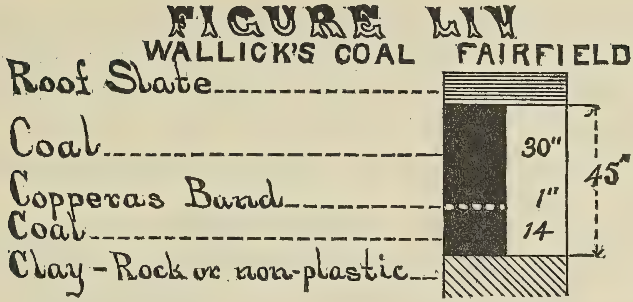


In Fairfield township there has been a large amount of coal mined for the salt works that have been established here many years. There are also several banks that have long been the reliance of the country about them.

The following persons are now mining this seam, viz.:

				Inches.
Joseph Koller	Section	9	—Coal,	48 to 60
Furney and Cullins	"	2	"	48
Thomas Scott	"	11	"	48
Peter Koller	"	12	"	48
J. T. Kennedy	"	13	"	48
Henry Wallick	Lot	10	"	45
Isaiah Christ	"	15	"	48
Mrs. Waltz	"	23	"	48

The structure of the seam on Henry Wallick's farm is shown in the appended figure:



Goshen township not only far outranks the other townships of the county, taken separately, in the production of coal, but it produces, in fact, very much more than all the rest combined. It is the only township in which any large shipping mines at present exist. The seam averages, throughout this district, 4 ft. 6 in. in thickness. It reaches its maximum of 5 feet in many instances.

The composition of the coal is shown in the following analyses:

No. 1. Pike Run mine, No. 1..*Lord.*
No. 2. Pike Run mine, No. 2, or Brock Hill mine.......................... "

	1.	2.
Moisture	2.98	2.69
Volatile matter	43.82	44.74
Fixed carbon	45.82	46.95
Ash	7.38	5.62
	100.00	100.00
Sulphur	3.24	3.09

These results are believed to fairly represent the seam throughout this district. In fact they are applicable to it throughout Eastern Ohio.

In physical characters the coal has much to recommend it. It has a fair degree of strength, being intermediate in this respect between the Massillon coal to the north, and the Cambridge coal to the south of it. It is rather hard to cut or undermine, and does not "shoot" to as much advantage as many coals. To blast it, there is required from 3 to 5 cents worth of powder per ton. It does not admit of being "shot off the solid," but must be undermined and "sheared" with proper care. The miner's

average output is 3 tons or possibly 3½ tons of clean coal. The screens in use are mainly 1¼ inches in the mesh. The nut and slack are generally run together, making a merchantable product, in demand for steam purposes.

Royalty is generally paid on clean coal, and the usual rate is 14 cents per ton of 2,000 lbs.

The round or lump coal is much valued for domestic uses in the county, but when compared with Massillon coal it is at somewhat of a disadvantage. Consequently when the coal reaches the lake markets it is mainly confined in its uses to steam production. It is a favorite fuel on lake steamers, and is widely used for locomotives.

The seam is in reality a three-benched coal, but it is often worked in such a way as to show only one main and regular parting.

The uppermost bench is an impure and slaty coal, that is locally known by the name of *cash*. This *cash* is generally left in the mine to form the roof, unless it is taken down in the main entries to give height. It gives a safe and permanent roof. Above the *cash*, which ranges from 4 to 8 inches in thickness, there are several feet of shale that slacks, upon the access of the air, and comes down in a dangerous way. In these roof shales are many large calcareous nodules or concretions, filled with beautifully preserved Coal Measure fossils. The shells of Producta are especially numerous and fine. These concretions will doubtless yield hydraulic cement when properly treated, as is inferred from their composition, but the number brought out may not be large enough to lend any value to the fact.

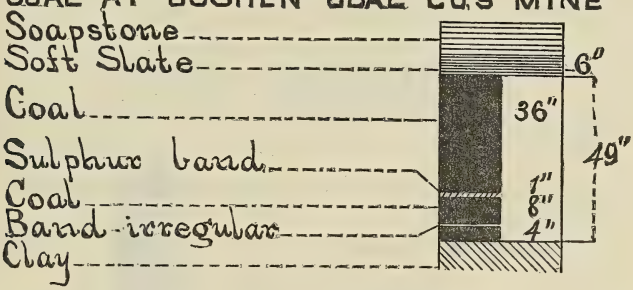
The floor of the coal is a soft clay. No rock intervenes between this seam and the next coal below, as a general rule. This fact necessitates the leaving of large pillars, which are from 21 to 25 feet in width. Rooms are generally worked 25 feet wide. The pillars are "gripped" at the entrance of the rooms, to confer additional strength.

The main parting of the worked portion of the seam is sometimes not more than 6 inches from the bottom, and sometimes it is as much as 21 inches. It is a sulphurous slate, and is known everywhere as the "copperas band." It finds market in Cleveland for the manufacture of sulphuric acid, and considerable quantities of it are shipped for this purpose. Other partings and slates are found in different mines or in different portions of the same mine, and masses of pyrites frequently occur.

The structure of the seam is further shown in the appended diagrams. The facts represented in these sections are drawn from different mines, but each mine will perhaps furnish examples of all the variations included in the diagrams, and more. The chief centers of production are represented here.

FIGURE LV

COAL AT GOSHEN COAL CO'S MINE



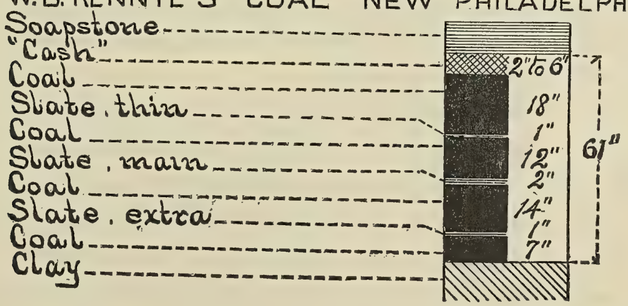
The Goshen Coal Company, A. W. Brown, Superintendent, ships coal by the Tuscarawas Valley Railway, and also by the canal. The mine is located under the well-known Goshen Ridge. It employs 60 or more miners, and has a present capacity of 150 tons daily. Its coal is extremely regular, the only interruption being found in small rolls in the floor.

The same statements apply to the Goshen Ridge mine, of Mathius, McFarland & Co., which employs 30 men, and ships coal by canal only.

The coal of W. B. Rennie's mine has the structure indicated in the next diagram :

FIGURE LVI

W. B. RENNIE'S COAL NEW PHILADELPHIA



The coal in this mine shows considerable "white cap" or encrusting calcite in the seams. This factor is thought to make the coal break

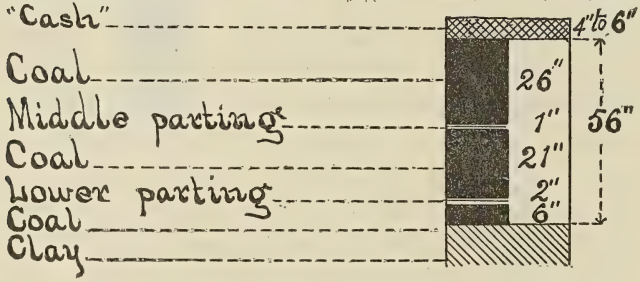
fine when blasted, and consequently the miners dislike to meet it in their workings. The coal of this mine is shipped by canal, exclusively, to the Cleveland market. The front hills are largely worked out under the ridge, and long underground hauls are necessary.

The Pike Run mines Nos. 1 and 2, the latter of which is also known as the Brock Hill mine, are by far the largest of the county.

The structure of their coal is indicated in the following figure, with the qualifications already made:

FIGURE LVII.

STRUCTURE OF COAL AT PIKE RUN MINES



These mines belong to the Tuscarawas Valley Coal Company, O. Young, Manager, Elyria, Ohio. They employ 225 men, and are shipping from 400 to 600 tons daily. The coal, like that of the last-named mine, is coated to quite an extent with calcite capping. The mines of this company are in excellent order. Ventilation is secured through a Champion fan, and the air is said to be as good as in any mine of the State.

There are in addition several other mines in the township, as the Walton Ridge mine, the Goshen Salt Well mine, the Groff mine, the Jones mine, and other smaller banks, but the statements already made cover fairly well the whole ground.

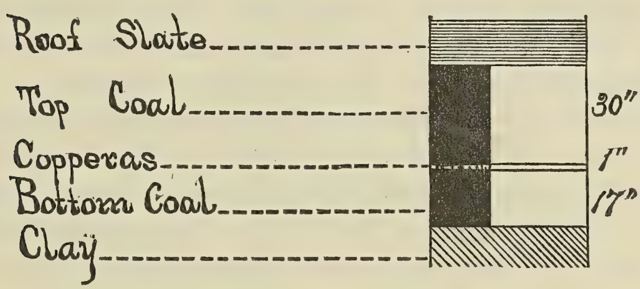
The coal of Warwick, Mill and Union townships deserves to be treated in the same connection with the Goshen coal, as all constitute but a single field. Mining has been extensively carried on in all these townships, along the lines of the railroads and canal, in past years, and the front hills are in many cases worked out. There still remain large areas of excellent coal lands, but a little less accessible than those portions already used. It is probable that the finest body of coal not yet reached in this district is to be found in Union township.

In York township there is one small shipping mine, and a large number of country banks now open in the Middle Kittanning seam (No. 6). The shipping mine is owned by H. Andermann, and leased to J. L. Edwards & Co., who furnish all the coal used in the Dover Rolling-mill. A small amount is also sold to outside parties. A question exists as to the reference of this coal. It may be the Lower Kittanning seam. The coal is in good condition here. It is 4 feet thick, mines large, is clean and bright, and has no more than the usual proportion of sulphur. The sulphur band is constant throughout the district, and occasionally an extra parting occurs. The coal of this mine burns with a white ash, but elsewhere the seam almost invariably leaves a purple ash.

The structure of the seam in the township is fairly shown in the accompanying diagram:

FIGURE LVIII

SECTION OF G. MATHIUS' COAL.



The country mines that were noted in the township are the following:

			Inches.	
Adam Limbaugh	Section 5	—Coal,	28	—Large amount of pyrite present.
Solomon Beaver	" 5	"	36	
W. Wolf	" 4	"	32	—Quality good.
S. W. Myler	" 3	"	42	—Good.
George W. Matthias	Lot 12	"	48	—Good.
Frederick Keizer	Section 24	"	58-60	—This may be the Lower Kittanning.
Susan Barkholder	Lot 13	"	60	
Phillip Hermann	" 39	"	62	
Franz Ankeney	" 5	"	48	
Jacob Kohler	" 10	"	50	
Wm. Gray	Section 17	"	48	
A. Fox	" 16	"	42	
G. Ginther	Lot 32			

In Jefferson township but very little coal is mined, but the two Kittanning seams are in the main persistent. The middle seam (No. 6) seldom fails, and it is worked in a few winter mines. The following list includes most of them:

			Inches.
Wm. Angel	Section 11	—Coal,	40
Eva Wolf	Lot 15	"	36
John Baker	Phillipsburg	"	36
Alexander Fenton	Section 25		
Abraham Lorenz	" 25		
Michael Wherly		Coal,	36
Mrs. Oesch	Lot 36	"	30
David Bucher	" 13		

All of these are red-ash coals of fair quality. The coals of the Kittanning horizon hold very close to the level of Stone Creek Valley, which is the railroad grade, through the part of the township traversed by it.

Salem township furnishes some of the most interesting and important geological sections of the county. It is traversed by the Tuscarawas Valley, which is carried below the Kittanning horizon, and the highest beds of which reach to the Barren Measures.

The Middle Kittanning coal is found here with its usual steadiness and constancy. It runs from 2 to 4 feet in thickness, as in the townships already traversed, and is the almost universal reliance of the community for the supply of fuel. It is or has been worked on almost every farm. The following named persons supply a little more coal than their neighbors, but there is not a shipping bank in the township:

Adam Stocker	Section 11	Coal,	24	in. thick.
Adam Kail	S. W. ¼, section 10	"	28	"
Conrad Stocker	Lot 16, Salem Tract	"	28	"
Richard Stocker	1 mile N. E. from Pt. Washington	"	30	"
Alvin Brough	Lot 11, Salem Tract	"	32	"
Enoch Wolf	Wolf Station	"	36	"
N. Bremer	Section 13	"	36	"
Phillip Arth	Section 3	"	36	"
David Rumbaugh	On canal, 2 miles from Pt. Washington	"	38	"
Andrew Stocker	Lot 23, Salem Tract	"	42	"

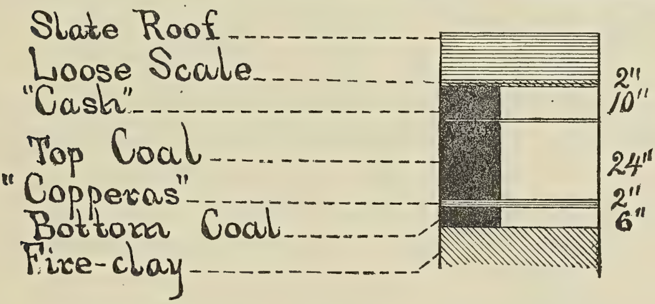
This list might be much extended, but the range of the coal is well enough shown in these figures. The coal is universally a red-ash coal. It agrees entirely with the descriptions already given of the seam.

The Lower Kittanning coal is not found in the township, so far as known, but both the Freeport coals occur, as will presently be shown.

The appended diagram represents the structure of the seam in its more moderate development:

FIGURE LIX

R. STOCKER'S COAL, NEAR PORT WASHINGTON.



The same conditions prevail in all essential respects in Clay township. The Putnam Hill limestone makes the lowest important stratum of the township. The fuel supply is mainly furnished by the same persistent seam that we are now following. At one or two points, however, the coal is characterized by some features that have not been before reported.

The following skeleton section illustrates the leading facts in the geology of the township:

Brush Creek coal, blossom		(No. 7*a*.)
Interval	50 feet.	
Upper Freeport coal	2 feet thick (No. 7).	
Upper Freeport clay.		
Interval, from coal to coal	120 feet.	
Middle Kittanning coal	4 feet thick (No. 6).	
Interval	68 feet.	
Putnam Hill limestone	3 feet.	
Brookville coal	1½ feet (No. 4).	

At the bend of the canal, near lock 17, the following short but interesting section is well exposed:

	Feet.
Lower Freeport sandstone, massive.	
Shale	10
Middle Kittanning coal	3
Interval	20
Lower Kittanning coal	2
Interval	45
Putnam Hill or Gray limestone	2
Brookville coal, thin.	
Fire-clay.	
Heavy sandstone.	

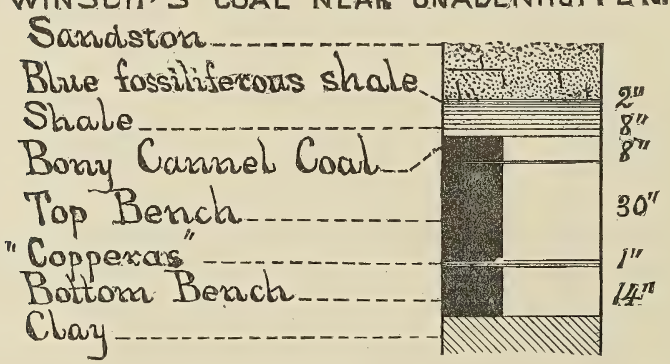
On the farm of Esq. L. S. Winsch, at Gnadenhütten, a section, including the coal now to be considered, is found. It is as follows:

	Ft.	In.
Lower Freeport sandstone, massive.		
Fossiliferous black shale	1	
Blue shale or soapstone		8
"Cash" or bone coal		8
Coal, middle or main bench	2	6
"Copperas band"		1
Coal, lower bench	1	3
Fire-clay.		

The structure of this coal is represented in figure LX:

FIGURE LX

WINSCH'S COAL NEAR GNADENHUTTEN.



There are several banks in the southern part of the township, about one mile north of the little village of Gilmore, that supply this immediate neighborhood. They are the Cochran bank, the Parker bank, and the Gilmore bank. The coal as worked here is rather thin, viz., 32 inches, and lies very near the drainage level, but it is hard and

black, and *it lacks the pyrite seam* that has been so constantly reported hitherto. But 2 or 3 feet below it another coal seam occurs. This lower seam is one foot or one and a half feet thick. At times the intervening clay thins out, and then we find nearly 5 feet of coal with only a thin clay parting. Formerly only this lower bench was worked. It was of poor quality, and it had a clay roof, which was troublesome, but convenience led to its being worked in the small way. But the falling in of the clay roof showed finally the larger and better seam above, and this only is taken now. The case is instructive. It shows the parting of the seam, which has been found to run steady over hundreds of square miles from one to three inches, suddenly expanding to as many feet, and then in places shrinking again to the normal measure. This line of facts will be found interesting in connection with others of the same general character that have been found elsewhere in this seam, and to which attention will be subsequently directed. It is unnecessary to name the many small banks from which the coal of this universal seam has been taken out within the township. It never misses its horizon, and is fairly mineable on every farm in which this horizon is reached, so far as known.

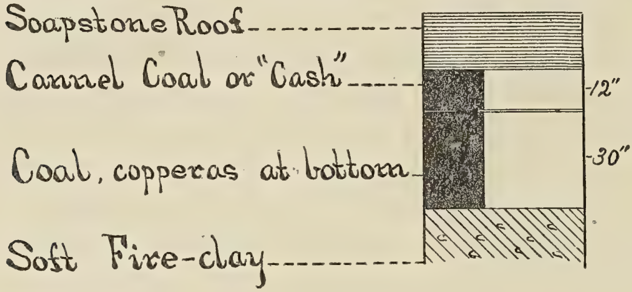
In Oxford and Washington townships we are reaching the line at which the Middle Kittanning seam falls below drainage. It is exposed in only the northwestern corner of Washington, in the valley of Dunlap's Creek. From this small district all of the coal of the township is derived. Five country banks cover the chief production. They belong to the parties named below:

Daniel Kees	Lot 29
Jesse Blair	" 25
John Fivecoats	" 17
Josiah Murphy	" 24
George Stoner	" 38

In all these cases the coal lies very low in the valley, having no more than the necessary height for convenient handling. At the Kees bank the "cash" has turned into a slaty cannel coal. It comes down easily and furnishes working height in entries and rooms. The coal is soft to mine, and is in good repute. Its structure is shown in the accompanying diagram:

FIGURE LXII

SECTION OF DANIEL KEES' COAL



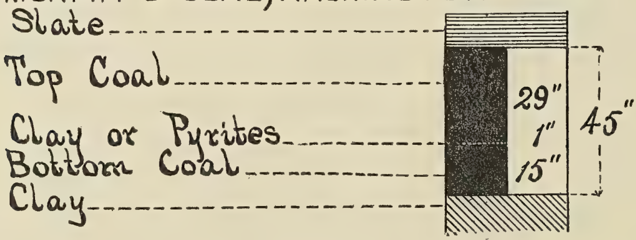
At John Fivecoat's bank we find the seam somewhat thicker. Its structure is as follows:

	Inches.
Slate.	
Coal, upper bench	29
Clay or copperas parting	1
Coal, lower bench	15
Clay.	

This mine produces much more than any other mine in the township. It is credited with 20,000 bushels annually. The Murphy bank is of the same general character. A section of the coal is shown below:

FIGURE LXIII

MURPHY'S COAL, WASHINGTON TWP.

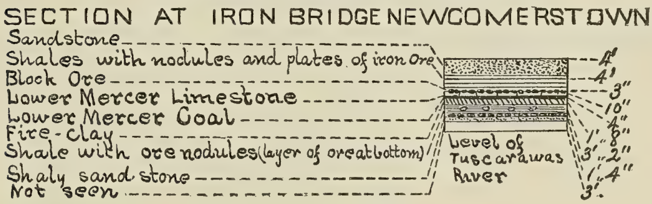


In the Tuscarawas Valley, at New Comerstown, Oxford township, we find excellent sections illustrating the general geology of the district.

At the iron bridge, just south of New Comerstown, there is a section of the Lower Mercer horizon of unsurpassed clearness. It is as follows:

	Ft.	In.
Sandstone.		
Shale with ore nodules	4	
Block ore		3
"Cone in cone"		2
Lower Mercer limestone		10
Lower Mercer coal..		4
Fire-clay.		
Shale, with balls of ore at bottom	1	8
Shaly sandstone	3	2
Concealed	1	4
Level of low water in river	3	

FIGURE LXI



Another section is found near Suydam's lock that includes more elements. It is as follows:

	Ft.	In.
Middle Kittanning coal (No. 6)	3	9
Interval	62	
Putnam Hill or Gray limestone	3	
Brookville coal (No. 4), thin.		
Interval	37½	
Tionesta (?) coal, overlain with sandstone	1	
Interval	7½	
Upper Mercer limestone	2	6
Upper Mercer coal, thin.		
Interval	22	
Lower Mercer limestone	36	
Lower Mercer coal.		

A still longer section from this vicinity is shown in Fig. XX.

Few additional statements are needed in regard to the coal. One peculiarity of it, in part of its extent, is the reduction or occasional disappearance of the lower bench of the coal and of the overlying copperas band. In such cases the thickness of the seam is correspondingly reduced. Where the seam is thus reduced, it generally measures 28 to 36

inches. The Lower Kittanning seam fails throughout this township, so far as now known.

Considerable disturbance of the series is shown in the tunnel, south of Newcomerstown. The coal that is cut in the tunnel has been faulted and doubled to an unusual extent for an Ohio seam.

The coal seam now under discussion has been followed through the central townships of the county, and has been shown to be universal in its distribution, and steady, if not generous in its development. It remains to indicate the leading facts as to the seam on the line of its western outcrop. This outcrop occupies parts of Franklin, Wayne, Sugar Creek, Auburn and Bucks township. The valley of the South Fork of Sugar Creek traverses these townships, and contains in the hills that bound it a fair showing of this seam as well as of the others that belong to the section. Quite a careful examination was made of this line a few years since by Professor E. B. Andrews, of the Geological Survey, in the interest of the Connotton Valley Railway extension. A number of facts gathered from his published report will be used in the succeeding brief account of the same district.

The Middle Kittanning seam (Coal No. 6) lies high in the hills along this line, and consequently its acreage is much less extensive than in the townships already reviewed. Coming southward from Stark county, it is first found in what is known as the Agnus Hill, in Franklin township, 2 or 3 miles south and west of Beach City. The coal has long been worked at this point. It has been mined mainly under light cover and is of comparatively small volume, measuring but 3 feet 3 inches, all told. The hill rises high enough in the ridge to which it belongs to furnish a scanty showing of the Freeport horizon, both of the coals being represented by "blossoms" at least.

A mile or two southward the seam is again worked in the Haas bank. It is 4 feet thick, and has a good name in the neighborhood.

Still further southward, and in Wayne township, we find the Shoup bank, the Baker bank and the Wallick bank, all in the same coal. The first of these openings shows unusual volume for this seam, the measurement reported here being 5 ft. 2 in. The coal of the Wallick bank shows a thickness of 4 ft. 4 inches. The bottom bench is 13 inches thick, and the parting 1 inch. The areas in all of these cases are limited by the fact already referred to, viz., that the coal lies high in the hills. The quality is of the usual Middle Kittanning type.

In Sugar Creek township there are several winter banks open in this seam. A little coal has been mined from it at Shanesville, but the seam is thinner here than at some other points. The Dummermuth, Funk, and numerous other banks, situated in the eastern part of the township, yield a considerable amount of good coal. The thickness of the seam ranges from 3 ft. 2 in. to 4 ft. 2 in., the increase occurring in the lower bench.

In Auburn township the mines of Lebengut, Buehler, the Zimmermans, and others, furnish a large local supply. The quality of the coal averages fairly well with the quality of the seam taken as a whole throughout northeastern Ohio, but it is not easy to see how certain claims that have been made for the coal of this particular region, as surpassing all other coals of the bituminous field, the Youghiogeny coal included, in calorific and evaporative power, could have originated, much less how they can be substantiated. The Lebengut coal as sampled from a freshly mined wagon load, shows the following composition:

Coal of Washington Lebengut's bank, Auburn township	*Lord.*
Moisture	3.66
Volatile matter	43.97
Fixed carbon	46.78
Ash	5.59
Total	100.00
Sulphur	3.79

These figures indicate the seam from which the coal is taken clearly enough, but they do not show by any means its highest phases. The amount of sulphur is large, and the ash is somewhat in excess of the best results. So also the fixed carbon is one or two per cent. below the average of the seam.

The bottom coal of the upper bench has a local reputation as a smith coal. The same portion of the seam is applied to the same uses in Stark county, as will be remembered in the description of the Osnaburg mines.

The Lower Kittanning coal seems to be wanting in the townships last named, and indeed throughout a wide territory in Tuscarawas, Holmes and Coshocton counties. A fossiliferous limestone comes into the series not far from the proper place of this coal in many sections. This limestone perhaps represents the missing coal, but the more probable reference of it is to the Ferriferous limestone horizon.

In Sugar Creek township a coal seam has been somewhat worked in past years that has been variously identified as Coal No. 3*a* (Upper Mercer), or Coal No. 3*b* (Tionesta). The interval between these coals is small, but from the facts given in regard to the occurrence of the last-named seam in Lawrence township, it seems more probable that the Winkelpleck, Yoedder and Nead coals, found near the center of the township, should be referred to the Tionesta horizon. Whatever the seam may prove to be, it is not likely to add very much to the fuel supply of the township, at least for some time to come. A good thickness is reported in several of these old openings, the coal ranging from 3 ft. to 4 ft. 2 in., but the seam is nowhere worked at the present time, so far as known. In other words, it does not appear able to maintain itself in competition with the upper seam of this same region.

The Middle Kittanning coal may be fairly inferred to extend throughout Bucks township, without serious interruption, as it is found in good development both to the west and east of the township. The land lies mostly in high, dividing ridges, that rise far above the horizon of the coal.

The Freeport Coals in Tuscarawas County.

Reference has been already made, in passing, to the several elements of the Freeport Group as they have come into view in the general sections that have been reported. Attention has been repeatedly called to the fact that the Upper Freeport coal is far less important in Tuscarawas county than the blackband ore that accompanies or replaces it in the central townships. The ore of this horizon will be treated of in another chapter, and a few statements will suffice for the coal.

The group as a whole is shown with great distinctness in all the townships of the county, except the four following, viz., Lawrence, Franklin, Wayne and Sugar Creek. Even in these there are occasional outliers that contain good exposures of the series, but the series shows no economic value, so far as is known.

The Upper Freeport horizon embraces, as will be remembered, a coal seam, a limestone and a clay deposit, in addition to the local accumulation of iron ore, to which reference has just been made. Of these the limestone and the clay are the most persistent. The former, indeed, is everywhere found at its proper level, constituting the best known of the buff limestones of the county.

The coal is nowhere mined by and for itself in any large way in this district. A few small banks are opened in it, but almost all the coal that the seam produces in the county is directly associated with the mining of the blackband ore. In thickness it seldom exceeds 2 feet. In quality it is always poor, chiefly from the abundant dissemination of scales of pyrites through all the joints of the coal. When the ore is mined, the coal is also taken. It is used to calcine the ore, and the farmers remove all surplus, which is sold at a nominal price.

There is, however, a singular duplication of the main seam at many points in this and in adjoining counties, and the supernumerary bed occasionally affords a fair chance for a winter coal bank. From 1 to 15 feet below the blackband coal, another seam, ranging from 1 to 4 feet in thickness, is often found. In quality it is never the best, but it is generally less impure than the regular seam. It is known to exist in Auburn, Jefferson and Salem townships, and its presence in other townships is fairly inferable.

The best showing of the two seams in the last-named township is in the northeast corner, on the farm of Paoli Bremer. Here also the interval between the two seams is reduced to its smallest proportions, viz., to a clay and shale parting of 6 or 8 inches only, the two seams aggregating 6 feet in thickness. The coal has been worked in past years to some extent, but its quality discourages operations in it at present.

On the Yackell ore hill, in the same township, the lower coal is 10 feet below the regular seam, and its quality is somewhat better here than at Bremer's. The seam is 4 feet thick, and a drift entry to the coal is kept open.

In Jefferson township the double seam is shown in most of the ore hills, but it has no importance or value. It lies from 10 to 15 feet below the blackband coal.

In Auburn township the double seam is shown in two of the ore hills, viz., the Shaw and the Cattcott hills. It ranges from 3 to 4 feet in thickness, and is about 15 feet below the regular seam.

This duplication of coal seams is an interesting phenomenon, which deserves more careful investigation than the Survey has been able to give to it. Examples have already been given of cases of this sort, in connection with the Clarion coal in Columbiana county, as well as with the Upper Freeport coal in the present instance. The same line of facts is to be reported for this horizon in Guernsey county and for the

Middle Kittanning seam in Perry county. The Diamond seam at Linton may also be looked upon as a twin or double seam, as will be seen by reference to the account given of that interesting and anomalous deposit.

In the present instance, facts have not been accumulated in sufficient quantity to warrant an attempt at explanation. The suggestion is offered that the lower seam may replace the Upper Freeport limestone, at the apparent horizon of which it is found. A wider examination of the field may show this suggestion to be inadmissible.

The Lower Freeport coal (No. 6*a*) is found at but a single locality of a single township in the county, so far as is known. The section referred to is shown in Fig. XX, A. It was taken on the tract made famous by the expensive plant and disastrous failure of the Glasgow-Port Washington Furnace Company. After locating in haste, the company proceeded to explore at leisure, and among the deposits investigated was an abnormal coal seam, that lies 40 feet below the blackband coal. The seam was exceedingly unsteady, ranging from 2 to 9 feet in thickness. Its appearance, when freshly mined, recommended it, but its quality was so sulphurous and impure that nothing could be done with it as a furnace fuel. Experiments were made in coking the seam and also in purifying the coke by washing the coal, but the quality was too poor to admit of any successful amelioration. This seam has strangely enough been confounded with Coal No. 6, or the Middle Kittanning seam, but there is nothing in common in the characteristics of this irregular and impure bed with the steady and serviceable coal seam that bears the latter name and number. Moreover, this latter seam is found in its own place, with all its normal qualities, 70 feet below the Lower Freeport coal, now under discussion, as shown in Fig. XX.

The Lower Freeport seam will, no doubt, be found at many points within the county, in the course of subsequent explorations. Its blossom is not infrequent in the hills, and it is known to be of fairly workable proportions on the eastern margin of the county.

VIII. COAL MINES OF GUERNSEY COUNTY.

The range of the Lower Coal Measures in Guernsey county is from the Putnam Hill limestone to the summit of the series, viz., the Mahoning sandstone. The Barren Measures are well developed through

the county, and yield a considerable local supply of coal from two or more seams. On the southern and southeastern borders of the county the Upper Coal Measures occur, and they here contain a fine development of the seam called the Cumberland coal by Professor Andrews. It is No 8*c* of Stevenson's sections, and the Barnesville coal of the present report.

The Lower Coal Measures are limited in their development to the deeper valleys of the northern and central regions of the county. The sections given in Figs. XVI, XVII and XVIII, of chapter I, serve to represent the general order.

The following seams of the Lower Measures are worked to a greater or less extent in Guernsey county at the present time, viz.:

Upper Freeport coal.
Lower Freeport coal.
Upper Kittanning coal?
Middle Kittanning coal.

Only the first and last of this series have any large or general value. They constitute Newberry's No. 7 and No. 6 of the Tuscarawas Valley. The remaining seams might be discarded without decreasing to any appreciable extent the coal production of the county. The Upper Freeport is the only one of these seams upon which any shipping mines are founded in the county.

The Lower Kittanning seam (Coal No. 5) also exists in fair thickness, and of good quality in the valley of Will's Creek, from Kimbolton southwards as far as Miller's Ford. Throughout this portion of the valley it cannot be said to lie above drainage in any profitable sense of the word, but it is just about level with low water for a considerable part of the territory.

At Kimbolton, Hon. T. S. Luccock reached the seam in a shaft sunk near his residence. The coal lies 38 feet below the upper seam, No. 6, and immediately below it the Kittanning clay was found, with a thickness of 20 feet. It is a plastic clay, and is white and promising.

At 68 feet below this seam the Putnam Hill limestone was struck. The same stratum is found a mile further down the valley on the land of J. S. Frame, where is has been quarried and burned for lime for a number of years. The quality of the coal found at Kimbolton was reported good.

The next shaft that reaches this seam in the valley is a trial pit at

Warden's Salt Works. It was sunk in 1881. The Middle Kittanning seam has been very extensively worked on the Warden farm for many years to furnish fuel for the salt works. The lower coal was found less than 30 feet below the last-named seam. It is reported to have been 4 feet and 9 inches thick. Judging from samples of the coal that were saved, the quality is excellent. The coal looks bright and hard and pure. The following analysis shows the composition of one of these fragments, and bears out fairly well the general judgment already expressed. The analysis is fully up to the standard of the seam:

Lower Kittanning coal, from trial pit at Warden's Salt Works........*Lord.*

Moisture	3.05
Volatile matter	39.27
Fixed carbon	50.12
Ash	7.56
	100.00
Sulphur	1.65

Still another shaft has been sunk to the coal in this neighborhood. Robert R. Miller found the lower coal 28 feet below the upper seam (No. 6) on his farm. A valuable section, including another coal seam, is to be found here. It is as follows:

	Feet.
Lower Freeport coal, mined formerly	$1\frac{1}{2}$
Interval	10
Lower Freeport limestone	1
Interval	65
Middle Kittanning coal, No. 6	3
Interval	28
Lower Kittanning coal	3

There is thus seen to be a deposit of the Lower Kittanning coal through a number of miles of the Will's Creek Valley, that gives fair promise of economic value. It certainly deserves to be more thoroughly tested, for there is an apparent promise of a large field of good coal.

The Middle Kittanning Coal (Coal No. 6).

This seam is confined within the same narrow limits which were assigned to the previously named seam. It is found above drainage in Guernsey county only in the deep valley of Will's Creek, in Wheeling and Liberty townships, and to a very slight extent in Cambridge. The

main working of the coal is limited to Liberty township. From Kimbolton, where it is found 85 feet above the level of Will's Creek, it can be followed up the valley by connected workings as far as Broom's Salt Works, where it lies 15 feet above low water. It descends below the valley in this immediate neighborhood. Throughout the territory included between these limits, it is or has been worked on every farm for local use.

The coal is found in a single bench, which varies from 30 to 36 inches in thickness. A sulphur and dirt band occurs below it, which seems to represent the parting in the seam that is so commonly found elsewhere. According to this view the coal consists of the upper bench of the main seam. The seam seldom yields fully 3 feet of coal, but when it is mined out, it leaves "a three-foot hole in the ground."

The quality of the coal is probably below the best standards of the seam, but it is still a well approved fuel for ordinary uses. The percentage of ash appears to be somewhat higher than usual, and, in short, the seam is gradually giving way in quality and quantity.

One opening to the seam, on Robert R. Miller's farm, shows 18 inches of coal, overlain by 18 inches of black fossiliferous slate, a fact that stands by itself so far, in the township. The immediate roof of the seam consists of a few feet of shale, above which a massive and distinctly conglomeritic phase of the Lower Freeport sandstone occurs.

The coal of this seam has kept in operation the several salt wells of the valley for a long term of years, and in furnishing this supply, a considerable acreage has been exhausted. The front hills, especially, have been robbed of their coal in the vicinity of the wells, so that it is becoming difficult in some cases to approach the undisturbed body of coal that lies behind them.

It may be counted sure that this seam will furnish in years to come a basis for considerable mining operations in the Will's Creek Valley. Its steadiness insures this result, despite the small measures reported here.

The Upper Kittanning Coal?

It will be remembered that a small coal seam has been reported in Jefferson and Columbiana counties as a normal element of the series between the Middle Kittanning and Lower Freeport coals. The same element seems to be shown in various sections in the Will's Creek

Valley. To it should be referred, apparently, a thin but very pure coal, mined in a very small way, and only for blacksmiths' use, on the Oldham farm, two miles northeast of Cambridge. A thin seam found many years ago in the bed of Will's Creek, in excavating for the foundation of a mill, in the village of Cambridge, testified to by Hon. Isaac Morton, belongs also at this level. Here, too, may perhaps be placed the seam that is reported by credible witnesses as lying about the level of Crooked Creek, west of Cambridge, and sometimes taken out of the bed of the creek. The seam has also been opened at Warden's Salt Works, in Liberty township, but it was too thin to admit of being worked. It adds nothing of value to the coal resources of the county.

The Lower Freeport Coal.

This seam is but of the smallest account in Guernsey county, but its place can be seen in numberless sections. One opening to the seam has been already noted. On Robert R. Miller's farm, in Liberty township, an entry was driven in upon the seam for a number of yards, but the thickness of the coal, which was 18 inches, did not warrant further work. The seam was here covered with 4 feet of blue shales. In the Tunnel section, near Cambridge, the Lower Freeport coal is also shown (see page 86). The coal is 15 inches thick, and is about 55 feet below the place of the upper seam.

The Upper Freeport Coal. (Coal No. 7.)

Not only is the Upper Freeport coal vastly more valuable in Guernsey county than all of the other seams combined, but the mining center to which it here gives rise, takes rank among the most important coal fields of the State. The coal of this seam is known in the markets as the Cambridge coal.

The seam comes in from the northward as the blackband coal. An important field of the blackband ore is found on Bird's Run in Oxford township, Tuscarawas county. It extends across the county line in some of its outliers. We find here the coal 15 inches thick, but very sulphurous and impure, so much so, in fact, that but little use is made of it. The noble deposit of ore, 6 feet in thickness, that overlies it, gives great value to the horizon, despite the worthlessness of the coal. The blackband is 143 feet above the Middle Kittanning coal. This horizon can be followed with ease and certainty through Wheeling and

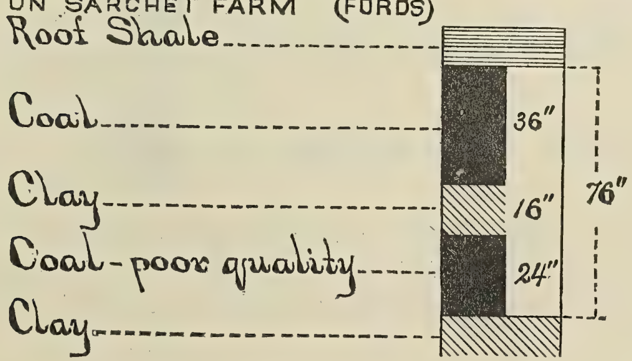
Liberty townships. It yields but little coal, so far as known, in Wheeling township, but in Liberty it gives rise to numerous small mines. The most northerly of these banks is that of Joseph Proctor in section 22, one mile east of Kimbolton. The following elements are shown in ascending from Wills Creek Valley:

		Feet.
Upper Freeport coal	Upper seam, formerly mined	$2\frac{1}{2}$
	Black shales, with plates of ore	6
	Lower seam, mined	3
Interval		50 to 60
Lower Freeport coal, chiefly cannel and black slate.		
Interval		70 to 80
Middle Kittanning seam		3

The seam is here apparently split, as at numerous points in Tuscarawas county. The two openings are not directly over each other, and the interpretation may be changed by further development, but the view given above seems the true one, as the facts now appear. Both seams have been worked, but the lower one only is mined at the present time. The quality of the coal is fair, as judged by the testimony of those that have used it, and by the appearance of the entry. In going southward, the occurrence of mineable coal at this level becomes more frequent, though still there are many points at which clay and limestone and black shales are very conspicuously displayed, without any coal being present, or else with a seam too thin to be mined. At Broom's Salt Works the coal was opened, showing but 16 inches in thickness. On the west side of Wills Creek, in section 24, Cambridge township, on the old Sarchet farm (now Ford's) the seam has been mined for a number of years.

FIGURE LXIV

STRUCTURE OF CAMBRIDGE COAL SEAM ON SARCHET FARM (FORDS)



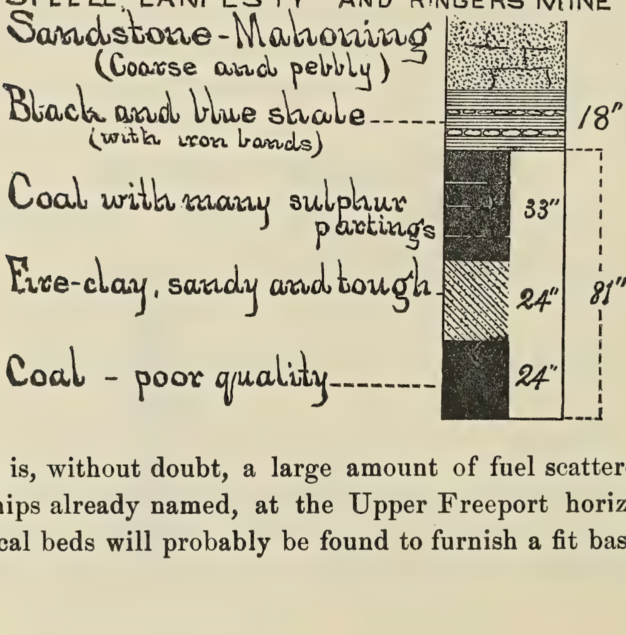
It is here doubled, but it is the upper bench that is chiefly mined. The structure of the seam is shown in the preceding diagram.

The lower coal is so sulphurous and impure, and the intervening clay is so hard and stubborn, that the miner finds no advantage in going below the main bench. A considerable quantity of coal has been taken from this bank. There are other showings of the seam of the same character in this and in the adjoining townships of Knox and Adams, and also in Westland township.

The duplication already described seems to be common, if not general, throughout this district. This structure is well exhibited in an entry driven in upon the coal by Messrs. Steele, Lanfesty and Ringer, in Westland township, near Cassell's Station. The double seam has fine volume, but the intervening clay is very hard to mine, and the lower coal is not of as good quality as the upper bench. The latter is divided by several inconstant sulphur "binders," but, on the whole, shows fair and marketable coal. A county mine on the Farrar farm, adjoining the last-named drift, has been worked for 30 years. Here, too, only the upper bench is taken, which is scant three feet in thickness, but of approved quality. The structure of the coal at the Ringer bank is shown in the following figure:

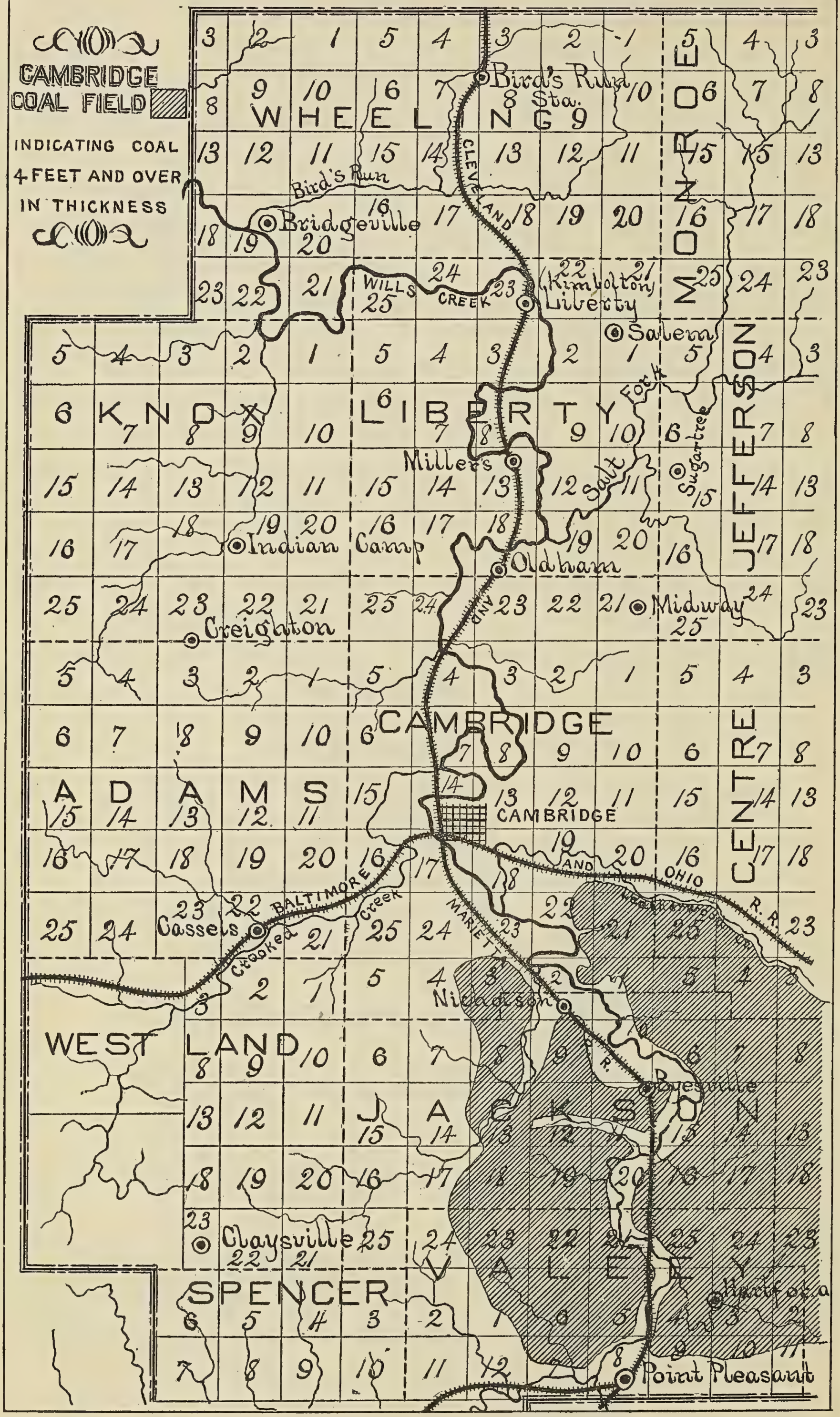
FIGURE LXV

STRUCTURE OF CAMBRIDGE COAL SEAM AT STEELE, LANFESTY AND RINGER'S MINE



There is, without doubt, a large amount of fuel scattered through the townships already named, at the Upper Freeport horizon. Some of these local beds will probably be found to furnish a fit basis for ship-

SKETCH MAP
OF THE WESTERN PART OF GUERNSEY COUNTY



ping banks in time to come, but in any case, small mines, but of considerable aggregate importance, are sure to be maintained in these deposits for a long period.

The Cambridge Coal Field.

We have now reached the confines of the great development of the seam in Guernsey county. In parts of Cambridge, Center, Jackson and Valley townships, the Upper Freeport coal scores its highest mark in Ohio. In quality the seam is nowhere else quite as good as here. In thickness the Cambridge coal has an advantage, at its best, of a foot above either of the other fields that are based upon this seam. In steadiness and persistency, though very much is to be desired, perhaps not quite as much is to be deplored as in the two eastern districts already described. There are several mines of large extent in which no interruption has yet been encountered, but in almost all, more or less serious "horsebacks" and "wants" are met. In a number of the mines, the interruptions of continuity have proved very unfortunate, but in no case have they brought complete failure to the mining enterprises established on the coal.

The Cambridge coal field does not extend to the limits of the village of Cambridge, but it occupies the southern tier of sections of the township. It goes under drainage not far from the eastern boundary of Cambridge, the Scott mine being the last that is level free. It extends, in its best volume and conditions, through the central portions of Jackson township, and through the northeastern sections of Valley township. In the main, the areas now described form portions of the valleys of Will's Creek and of Leatherwood Creek, from which, and from the minor tributaries of which, the coal has been, in all instances, attacked. The seam goes under drainage near Byesville, in the center of Jackson township, but some of its most important mines are located at and beyond this point.

The Cambridge coal agrees with the product of the other fields of the same seam already described, in both physical and chemical properties. Like the Big Vein of Salineville, and like the Dell Roy seam, it is a bright, well-jointed coal, mining in large, oblong blocks, but lacking strength to bear transportation well. The Cambridge coal is also, like the Upper Freeport seam in the other fields that have been

named, a two-benched coal, the lower bench averaging 1 to $1\frac{1}{2}$ feet, and the upper bench running from 3 to 5 feet in thickness. The upper bench has no regular slates or partings, but it is seldom found without *irregular* bands that give rise to considerable "dirt" in mining.

It cuts easily, but does not bear powder in excess. Three cents worth of powder is enough for a ton of coal. Like the coals above named, also, it has a definite chemical type. It averages 53 per cent. of fixed carbon, and about 37 per cent. of volatile matter. It is moderate in water and ash, but rather high in sulphur. These facts have been already shown to belong to the seam generally, and to be as characteristic of it as any facts in its physical structure.

It remains to describe in brief terms the leading mines established in this field. There are two sections of them, viz., those established on the Baltimore and Ohio Railroad, along Leatherwood Creek, east of Cambridge, and those established on the Wheeling and Lake Erie Railway (formerly Cleveland and Marietta Railroad), in the valley of Will's Creek, and its tributaries south of Cambridge.

There are four mines in operation along the line of the B. & O. Railroad, east of town. They are named as follows:

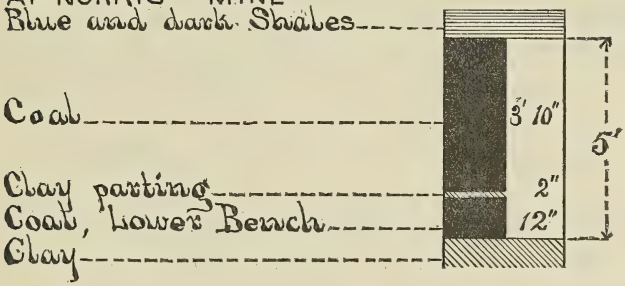
Guernsey mine.
Cambridge mine.
Scott mine.
Central or Norris mine.

The first three of these have been established for a number of years, and a large acreage is already exhausted.

The Central or Norris mine includes 350 to 400 acres of coal, in the southwestern corner of Center township. The coal has a natural thickness of 5 feet. It sometimes gains two inches, and sometimes loses one or two in its undisturbed portions, but in the main it holds the measures above given. The structure of the seam is shown in the following figure.

The bottom bench is thought to contain the best coal, but it is somewhat more tender than the top coal, and as the "bearing in" is done in this portion of the seam, it is brought out mainly as small coal. The upper bench mines in large blocks, but it bears neither transportation nor storage well. It is used almost exclusively for the production of steam, a large part of it being taken by the railroad company for its locomotives. It is well approved for this purpose, kindling easily,

FIGURE LXVII
STRUCTURE OF CAMBRIDGE COAL SEAM
AT NORRIS' MINE



showing good evaporative power, and making but little troublesome clinker. The coal is cleaned by screens that are $1\frac{1}{4}$ inches between the bars. These screens remove from one-third to one-half of what is sent out in the bank-cars. The railroads are coming to use more of the smaller grades of coal, one-sixth of nut coal being taken with the lump coal in many contracts, but the slack and smaller grades of coal are for the most part entirely lost.

The bank-cars are brought out by a wire cable, the Norris mine being one of the first in the State to succeed with this apparatus. The main entry is worked "quartering," for the sake of making a straight course for the cable. At 110 yards from the bank mouth a "horse-back" of Mahoning sandstone was struck. The coal was cut down to the slate parting. The entry was pushed forward through the rock for 125 yards, without finding steady coal, and the question was raised whether the advance was not being made along the axis of the sandstone trough. The coal will accordingly be attacked from other directions. Clay veins come in to complicate the mining, and reduce the quality of the coal. Three of them occur within 60 or 70 yards on the west side of the trouble. "Slickensides" is common in the coal, and reduces the strength of the pillars. One-third of the whole seam is left in pillars, and these latter are hard to win, and are quite largely lost.

The composition of the coal from this part of the mine is somewhat below the standard, but it is believed that there is a large body of excellent coal tributary to this mine, and that its last days, which are very far away, will thus prove to be its best days.

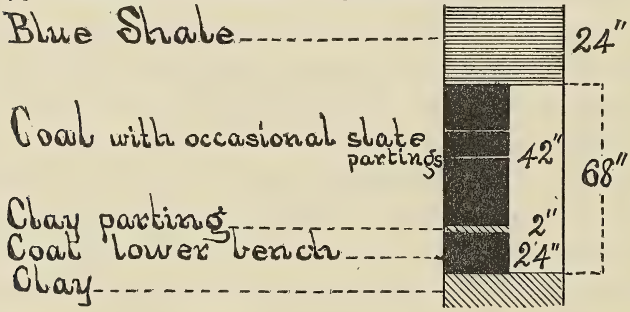
Analysis of the output shows the following results:

Coal of Norris mine	*Lord*
Moisture	2.91
Volatile matter	37.84
Fixed carbon	51.07
Ash	8.18
	100.00
Sulphur	3.13

The Scott mines that come next below are located in Cambridge township, and are among the oldest mines of the district. The Salt Works located here antedate the railroad by many years, and a considerable acreage has been devoted to them alone. The conditions are the same in all particulars as in the Norris mine, except that not as much trouble has been met in the working of the coal. The structure of the coal is shown in the following diagram:

FIGURE LXVI

STRUCTURE OF CAMBRIDGE COAL SEAM AT SCOTT'S SALT WORKS



The fire-clay floor is somewhat troublesome in this mine. The roof is hard and heavy, and unless very large pillars are left the floor rises at once. Pillars of 40 feet have given way once and again, and there are now left pillars of 90 feet. It is estimated that 18 inches of the seam under ordinary mining turn into slack, which has, at present, no market.

In some of the sandstone troughs encountered, all of the coal has disappeared. The Upper Freeport limestone is always present in the clay below the coal.

The Cambridge Coal Company's mine is next below, and the Guernsey mine completes the list on Leatherwood Creek. These four

mines are essentially one body of coal, all of the conditions agreeing throughout. In the latter mine an entry was driven for 225 yards through solid sandstone, the coal being almost entirely cut away, but as the entries are followed further to the southward the coal grows more steady and reliable. The quality is here at its best, as is shown in the analysis of the following average from the Guernsey mine:

Coal of Guernsey mine	*Lord.*
Moisture	5.32
Volatile matter	37.46
Fixed carbon	53.29
Ash	3.93
	100.00
Sulphur	1.38

The coal of that part of the field to the south of Cambridge, viz., the Will's Creek Valley, is much superior to that which has its frontage on Leatherwood Creek. As has been already stated, the Leatherwood mines all strengthen and improve to the southward, where they in substance establish connections with the mines of Will's Creek.

The following shipping mines are now established in this part of the Cambridge coal field:

Ohio Coal Company's or Nicholson mine	Two miles south of Cambridge.
Manufacturers' Coal Company's mine	Byesville.
Akron and Cambridge Coal Company's mine	Byesville.
Buffalo Coal Company's mine	Hartford.

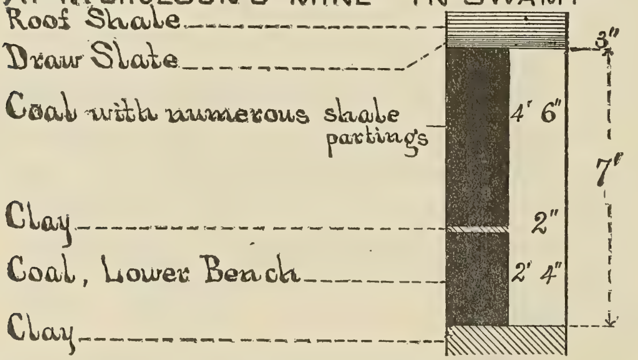
Two other new banks have been recently opened. The body of coal represented and commanded in large part by these mines, is one of the noblest coal areas of the State, second only in volume and steadiness, and general good quality combined, to the best portions of the Hocking Valley.

From the interruptions and breaks described as characterizing the Leatherwood mines, this portion of the field is happily free, at least to a great extent. Two of the four mines named above have each worked out a large acreage without coming upon a single horseback or other intrusive element. The Nicholson mine, which is one of the two referred to, does not even report a single clay vein. In addition, this mine carries fully 7 feet of coal through a large swamp, and never falls below 5 or 5½ feet. Its coal is also a little harder than that of the

mines already reported. The best coal is in the lower bench, which is here $2\frac{1}{2}$ feet thick, and consequently a good deal of it is brought out in merchantable shape. The uppermost part of the seam is the hardest and strongest coal, and immediately over the main parting a softer portion occurs. In addition to the main parting, which is a two-inch slate, there is one regular band about two feet below the roof of the seam, and there are the usual "binders."

The structure is shown in the accompanying plate:

FIGURE LXVIII
STRUCTURE OF CAMBRIDGE COAL SEAM
AT NICHOLSON S MINE IN "SWAMP"



The composition is shown in the following analysis:

Coal of the Nicholson mine	*Lord.*
Moisture	3.84
Volatile matter	37.90
Fixed carbon	53.83
Ash	4.43
	100.00
Sulphur	1.36

It is apparent that such figures mark one of the finest coals of the State. The physical qualities of strength and hardness alone are lacking to make this the peer of any Ohio coal.

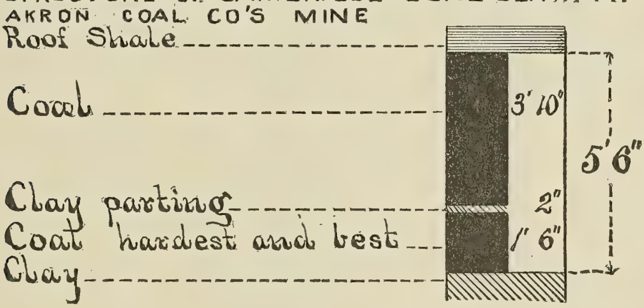
The Akron and Cambridge mine at Byesville is another of these regular and uninterrupted bodies of coal, without horsebacks or clay veins. Its composition is shown in the appended table:

Coal of Akron and Cambridge mine	*Lord.*
Moisture	3.30
Volatile matter	35.85
Fixed carbon	54.13
Ash	6.72
	100.00
Sulphur	1.68

Its structure is shown in the following plate:

FIGURE LXIX

STRUCTURE OF CAMBRIDGE COAL SEAM AT AKRON COAL CO'S MINE



The coal, as will be seen, holds a thickness of $5\frac{1}{2}$ feet. Of what is sent out by the miner, 40 per cent. goes through an $1\frac{1}{4}$-inch screen. Much of the product of this mine goes into market as "run of mine," which is known here by the local name of "brush coal." A Harrison mining machine is in successful operation here, and the mine is making a large output.

The same general statements apply to the mine of the Manufacturers' Coal Company, which adjoins the mining property last named.

The last large mine opened in the seam in ascending the Will's Creek Valley is that of the newly opened Buffalo Coal Company, at Hartford. The coal lies 50 feet below the bed of the creek. It is 6 feet thick, and of excellent quality, as is indicated in the appended table:

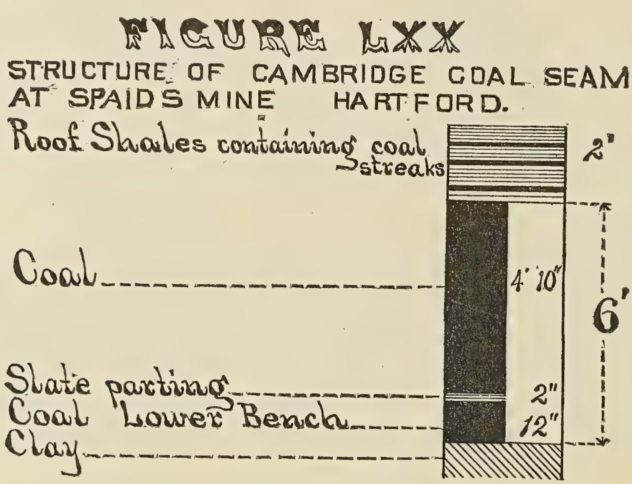
Coal of Buffalo mine	*Lord.*
Moisture	3.97
Volatile matter	34.78
Fixed carbon	56.32
Ash	4.93
Total	100.00
Sulphur	.79

This composition, if maintained, will entitle the coal to a leading place, not only in this field, but in the State at large. There are few mines in Ohio that yield better results than those given above.

Some irregularity was found in driving northward from the shaft, the [trouble being due, as usual, to a horseback of sandstone, which reduced the coal. The direction of the sandstone trough, as far as could be judged at the time this record was made, seemed to be northwest. It is claimed that drillings have established the existence of the seam in good condition to the northward of this property.

A peculiarity of this mine is the partial replacement or conversion of the draw slate into an impure coal. In some cases, layers of coal one or two inches thick come into the slate, and in others nearly a foot of unmarketable coal is added to the seam.

The pillars of the mine have been so far left 25 feet wide. The bottom is harder than in the northern mines, but if pillars of this size can maintain the entries, very different conditions will be shown here from those that obtain in the remainder of the field. The structure of the Hartford coal is shown in the accompanying plate:



As to the limits of the field on the south and west, it is not possible yet to speak with assurance. Exploration has not, by any means, been carried far enough to assign boundaries. Experience from similar fields justifies the belief that many additions will be made to the first found areas.

Some drilling has been done to the south and west of Hartford, and, so far as reported, this does not indicate the maintenance of the seam in good condition in this direction. There are conflicting reports as to the results of drilling to the east of Hartford. To the north and east of Byesville, considerable investigation has been carried on, with some encouraging results. There is a good body of coal in the southwestern corner of Cambridge township. It has long been mined for the supply of the town. The Stoner bank is the largest in this neighborhood. The coal of the Stoner mine ranges from 4 to 5½ feet in thickness, and the quality is well approved.

These statements complete the account of the mines of the Cambridge coal field, and they will be found to justify the assertions with which this account was begun, viz., that we have in this district a body of coal that deserves to be ranked among the best of the present centers of mining in the State.

The Post Boy Borings.

An account of the coal resources of Guernsey county would not be considered complete if it contained no reference to the widely published claims of the discovery, within the last few years, of a valuable basin of the Sharon or Brier Hill coal, in Wheeling township, not far from Post Boy Station.

The principal facts in connection with this claim are as follows: In the drilling of three deep wells in search for petroleum on the farms of James and Daniel Booth, in the valley of Bird's Run, several years since, a coal seam was reported at about 260 feet below the surface. In one well the seam was reported to be 5 feet thick; in another, 18 inches thick; and in a third, which was but 100 yards distant from the first, no coal was found.

Two years since, a company was formed by citizens of New Comerstown and vicinity to drill for oil on the farm of Joseph Norris, one mile south of Bird's Run Station. The drillers were instructed to proceed with special care when the horizon of the coal reported in the Booth wells was approached, though the company had not secured title to anything but oil. At about 170 feet below the surface, the Booth seam was struck. Its thickness was made out to be 9 feet and 2 inches by the drillers, as reported by Mr. Norris. The reamer was put down, and specimens were saved with great care from every foot. In par-

ticular, a three-fold division was made of the samples brought up, into top, middle and bottom, of the seam. The samples submitted by Mr. Norris scarcely constitute a true coal seam. There are particles of bright coal among them, but the bulk of the seam, as judged from the facts above given, consists of a peculiar carbonaceous deposit, that is nearer to a coarse cannel than anything else, though it lacks the conchoidal fracture of cannel. It is without luster, has no joints or faces, and shows no lines of deposition. The samples guaranteed by Mr. Norris, as representing the top, middle and bottom of the seam, were submitted to chemical analysis, with the following results:

Analysis of "coal" from Post Boy well.......................................*Lord.*

1. Upper portion of seam.
2. Middle portion of seam.
3. Lower portion of seam.

	1.	2.	3.
Moisture	2.80	3.11	3.04
Volatile matter	31.39	33.42	35.06
Fixed carbon	43.95	40.44	44.56
Ash	21.86	23.03	17.34
Total	100.00	100.00	100.00
Sulphur	0.76	0.92	0.70

The claim has since been made that all of the samples analyzed came from the upper portion of the seam, and that a bed of bright coal is found below. It is possible that the true order of the facts was not carefully enough determined while the work was going forward. If this is the case, all statements in regard to the facts are clouded, but judging from the statements submitted, the deposit does not seem to be a valuable one. The average of the ash of the three specimens is 20.74 per cent. This fact will rule the product of the seam out of present markets. The percentage of sulphur is remarkably low for a deposit of this character.

The character of the bed is settled by the statements already given, as far as the facts that are furnished will warrant, but a question remains as to the geological position of this interesting deposit.

The Middle Kittanning coal is mined near the well's mouth, but about 40 feet above it. On the farm of Anderson Gibbs, near by, the Gray or Putnam Hill limestone is found 72 feet below the above named coal seam, but in the next township this interval ranges from 87 to 100 feet. In drilling the wells to which reference has been made, a blue limestone has been repeatedly struck, about 70 feet below the Gray limestone. This matches well to the Lower Mercer horizon, as found in the northern outcrops. The bottom of the seam in question is about 80 feet below this last-named limestone. These facts can be combined and shown in tabular form as follows:

Middle Kittanning coal (Coal No. 6).	
Interval	40 feet.
Well's mouth.	
Interval	32 feet.
Gray or Putnam Hill limestone.	
Interval	70 feet.
Blue or Lower Mercer limestone ?	
Interval	70 feet.
Norris coal	9 ft. 2 in.

According to this scheme, the stratum in question would be not far from the place of the Sharon coal to the northward. The interval would be shorter than we should expect, but while questionable, this interpretation would not be entirely inadmissible.

The actual section, as shown in the records of the Norris well, does not, however, match well to this scheme. The section is as follows, stated in terms of the drillers:

	Feet.
Soil and loose earth	15
Bluish sandstone	45
First coal	1
Light sandy shales	44
Hard sandstone	4
Floating sand	14
Black shale	7
Sand	4
Second coal	1¼
Black shale	4
White sandstone, changing to blue	23
Soft sandrock	4
Fire-clay	1
Norris coal	9⅙

Recasting this section, and omitting all but the coals, and also prefixing the Middle Kittanning coal, as in the previous arrangement, we find the order shown below:

Middle Kittanning coal.	
Interval	100 feet.
First coal seam.	
Interval	73 feet.
Second coal seam.	
Interval	32 feet.
Norris coal.	

There is no hint in the drillers' record of any limestone or other characteristic element, except the coals. We are thus left quite uncertain as to the equivalence of these elements in the general section. Were it not for the presence of the two limestones named in the first table, in territory so near the Norris farm, a more satisfactory identification of the coal seams would appear to be found in referring the Norris seam to the Lower Mercer horizon, the second coal to the Upper Mercer horizon, and the first coal to the Brookville seam. This would make the intervals abnormal in the way of increase, very much as the other scheme renders them abnormal by reduction.

A definite answer cannot therefore be given at this time as to the place in the series to which the coal of the Post Boy boring belongs. As between the two references suggested, the latter would seem to have most reasonable support in the facts of the general section, and the former in the facts of the particular section.

The Lower Coal Measures, as developed in the remaining counties of the Ohio coal field, will be discussed in subsequent chapters.

CHAPTER IV.

COAL MINING IN OHIO.

By Hon. Andrew Roy, State Inspector of Mines.

Early Coal Mining in England.

The art of coal mining originated in England. The savage and roving tribes who inhabited Britain at the time the island was invaded by Julius Cæsar, were doubtless acquainted with the use of coal, and mined it with tools of wood or flint before the use of iron was understood.

The Romans, while in England, the Anglo-Saxons and the Anglo-Normans were acquainted with the coal beds, and used coal to some extent.

Coal is not, however, expressly mentioned in English History until the year 1180, in which year the Bishop of Durham granted lands containing coal to be mined for blacksmithing purposes.

By the beginning of the Fourteenth Century, coal had found its way to London, and was largely used by the common people, as being cheaper than wood, but its use was unpopular, and an outcry arose against it.

In the year 1306 the Lords and Commons assembled in Parliament on behalf of the citizens of London, petitioned King Edward the First to prohibit the use of coal in the city, and the King issued his Royal Proclamation forbidding its use in London and the suburbs, and commanded that all furnaces and kilns which burned coal be destroyed; but notwithstanding the royal mandate, the ostracised mineral continued to be burned, and twenty years later found its way to the royal palace itself. The use of coal was again prohibited in London by Queen Elizabeth during the sitting of Parliament.

On the Continent of Europe the mines of Zwickau, in Saxony, were worked in the Fourteenth Century, and in the years 1348 the metal workers of Zwickau were forbidden to use coal in their establish-

ments. In Paris the introduction of coal met a similar fate; it was condemned, and its use forbidden; it was accused of polluting the air, producing disease of the chest and lungs, and even impairing the beauty and delicacy of the complexion of ladies.

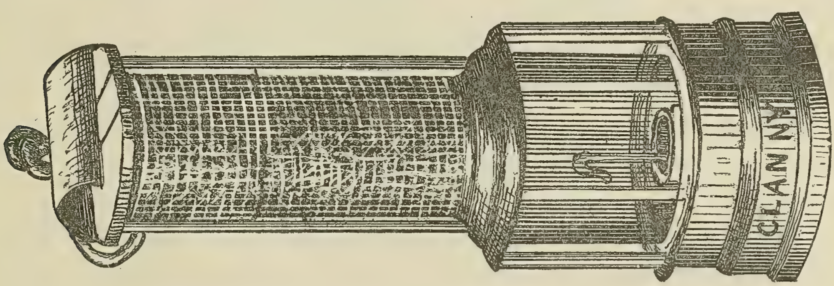
The manner of mining in these primeval times was necessarily rude. At points where a seam of coal exposed itself along its line of outcrop, the alluvial cover was stripped off, and the coal quarried in open day, as beds of sandstone for building purposes are now quarried out. When necessity required an opening to be made under cover, the seam was followed along its line of strike, in order that the waters of the mine might discharge themselves by gravitation. The double-headed pick, still the main weapon of the miner, has been in use from the earliest times. A thousand years ago this mining tool was as perfect as it is to-day, and the miner of the ninth century could produce as much coal from his working place as the miner of the nineteenth century.

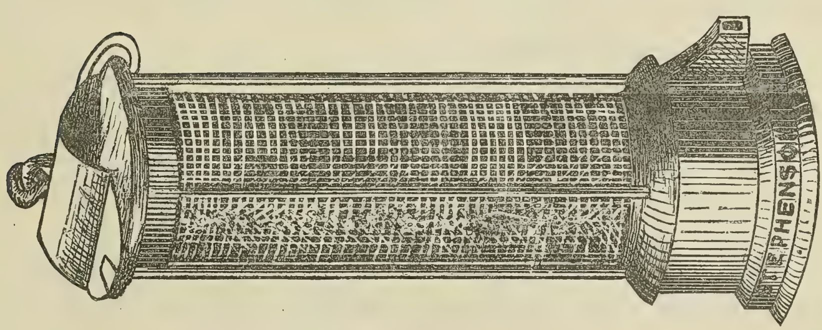
When increasing demand for coal made it necessary to open mines below water level, the seam was opened either by following it along its line of dip, or by sinking a shallow shaft near the outcrop. The horse-gin, still to be found in some mining districts, was employed for hoisting coal. The machinery used for discharging the waters of the mine consisted of ox-skins and barrels; then chain-pumps were applied, operated by horse-power, or by wind-mills. Frequently day levels were cut at great labor and expense to a lower level, or adit, so that the water might flow to day. In locating a shaft, a primary object was to find a place near the opening, so that a day level might be cut to rid the mine of water. In laying out the workings, small pillars were left to support the roof, which were abandoned after the room workings were finished.

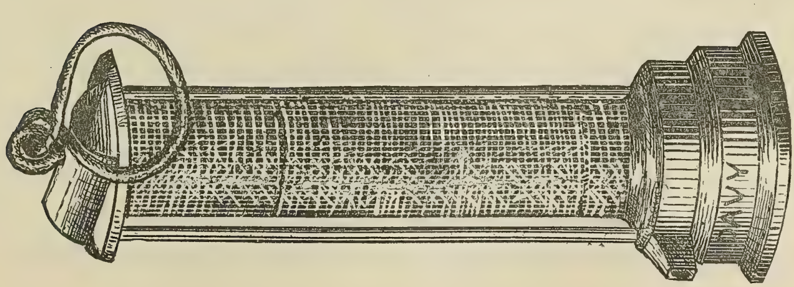
When shaft mining was commenced, fire-damp, that dreaded scourge of coal miners, was met. Until the discovery of the safety-lamp by Sir Humphry Davy, the miner possessed no means of detecting the presence of this gas in his subterranean workshop, except by creeping forward inch by inch, with his candle held in one hand, screening the flame with the two fore-fingers of the other, and fixing his eye intently upon the light. When he reached the fire-damp, the flame of his candle began to elongate and to assume a color of grayish blue; before the gas exploded, the top of the flame changed to a pure fine blue and gave off minute luminous sparks. The miner could still retreat before explosion

occurred, though this was the extreme point of danger: a sudden motion of the body, or a quick lowering of the light would ignite the fire-damp. The art of ventilation at this time was so little understood, that as soon as mines began to make fire-damp copiously, the workings were abandoned.

Sir Humphry Davy invented the miners' safety-lamp in 1815, and presented it as a gift to the miners. After this discovery, mines which had been abandoned, owing to the presence of fire-damp, were reopened, and millions of acres of mining property, otherwise unworkable, were made available to mining enterprise, though, as the results show, too often at the terrible sacrifice of human life.







Until the year 1775 the coal was carried from the working places of mines to the pit bottom on the backs of bearers, who were often married women, or full-grown girls, clothed in the same garb as the men. In Scotland the female bearers carried the coal to the top of the pit on a long and winding stairway. The coal was carried on wicker cribs fitted to the backs of the bearers, the cribs being held in place by leather straps passing around the forehead. The shameful practice of employing females in coal mines was continued until the year 1842. In Belgium this degrading practice still exists.

At the beginning of the present century the output of the mines in England, Scotland, and Wales had reached 10,000,000 tons, giving employment to 20,000 miners. The mines, prior to this time, were generally located in remote districts, and the miners were regarded as outcasts, and were debarred the common rights of other artisans and laborers; they were grossly ignorant and brutal, and in dialect and appearance were altogether different from people in the surrounding country.

They are described in Southey's life of Wesley as a race as lawless as the foresters, their forefathers. When the famous preacher Whitefield proposed going to America to preach the gospel to the Indians, many of his friends replied: "If you desire to convert savages, there are colliers enough in England."

The discovery of the steam-engine, and its practical application to mining purposes gave the coal trade its first impetus. This was soon followed by the discovery of the manufacture of gas, the hot-blast for smelting iron, the steam-boat, and the railroad locomotive, which made the use of coal the main spring of our present civilization.

With the development of the coal trade, consequent on the discovery of steam, the underground workings of mines were extended in size and depth, increasing the danger of mining, and necessitating new and improved systems of working. In sinking deep into the earth's crust the miner encountered obstacles, the most difficult and dangerous ever met in human enterprise. Intricate galleries, extending miles underground, were required to be maintained for the constant passage of atmospheric air, to dilute and render harmless the noxious and poisonous gases of the mine; massive columns of coal had to be left unwrought in the mines to maintain the superincumbent strata in place, machinery of great weight and power had to be applied for lifting coal

and removing the vast subterraneous lakes of water, while forests of prop-wood had to be planted underground to insure safety to the hauling roads and working places of the mines.

Fire-damp, that dreaded and fatal enemy of the English miner, was given off in increasing and alarming volumes. The rude systems in use before the application of steam to mining were totally unfitted for the deeper and extensive mines, which followed the application of Newcomen's engine for lifting water. The increasing weight of the superincumbent strata produced crushes by which the pillars of the mine were ground to pieces, or creeps which overran the workings, the pillars sinking into the floor, and destroying the economy of the whole underground arrangements. New systems had to be devised, adapted to all the varying conditions and circumstances.

A number of eminent mining engineers, notably Robert Bald and John Buddle, devised new and improved methods of laying out the underground workings of mines, and in British practice there are four general systems now in use, a brief description of which may not be out of place in this paper.

Different Systems of British Mining.

There are four general systems in British mining practice, as follows:

1. Working with pillars and rooms, and leaving pillars of no greater strength for the support of the superincumbent strata than is actually necessary as the workings progress.

2. Working with pillars and rooms of extra size and strength, with the object of attacking the pillars in the interior of the mine, and removing them after all the rooms have been finished up, partially or bodily, according to circumstances.

3. Dividing the workings up into pannels or squares, and drawing the pillars of the pannel after its rooms have been finished during the forward progress of the work.

4. Laying out the workings on the long-wall system, and mining out all the coal, leaving no pillars whatever, as the excavations advance progressively forward.

There are many modified plans of the above systems in use, as, for example, in working by long-wall, the main galleries of the mine are

sometimes driven forward to the boundary of the mining property before the walls are opened out, and in excavating the coal, the miners retreat instead of advancing with their work; sometimes, also, in pillar and room practice the same plan is adopted, the main galleries of the mine being driven to the boundary before any of the rooms are opened out.

Mr. Robert Bald has given the following general rules for determining the best method of working coal by pillar and room practice:

1. If the coal, pavement, and roof are of ordinary hardness, the pillars and rooms may be proportioned to each other, corresponding to the depth of the superincumbent strata, providing, all the coal proposed to be wrought is taken away by the first working; but if the pillars are to be winged, or partially worked afterwards, they must be left of an extra strength.

2. If the pavement is soft, and the coal and roof strong, pillars of an extra size must be left, to prevent the pillars sinking into the pavement, and producing a creep.

3. If the coal is very soft, or has numerous open backs and cutters, the pillars must be left of an extra size, otherwise the pressure of the superincumbent strata will make the pillars fly or break off at the backs and cutters, the results of which would be a total destruction of the pillars, termed a crush or sit, in which the roof sinks to the pavement, and closes up the work.

Regarding the long-wall system, the late Matthias Dunn gives the following conditions under which it may be adopted to advantage:

1. If the coal be thin, hard, and capable of bearing pressure, or the top and bottom be soft, requiring a considerable quantity of cutting for the necessary tram height.

2. If band or rubbish be mixed with the coal, requiring to be stowed underground, so as to furnish a cheap and plentiful supply of debris for filling.

3. If the distance from the shaft to the boundary line be limited.

4. If the roof be free from water, and the workings clear ot buildings, rivers, etc.

5. If the roof contain ironstone, to be worked with the coal, thereby producing much refuse, or if it be so soft and brittle that it will not stand for ordinary pressure.

Under these, and many other circumstances, the long-wall system

may be recommended. There may, however, be objections, rendering such working impracticable, viz.:

1. If the workings produce a considerable quantity of inflammable gas, either from the seam itself or from some superior seam.

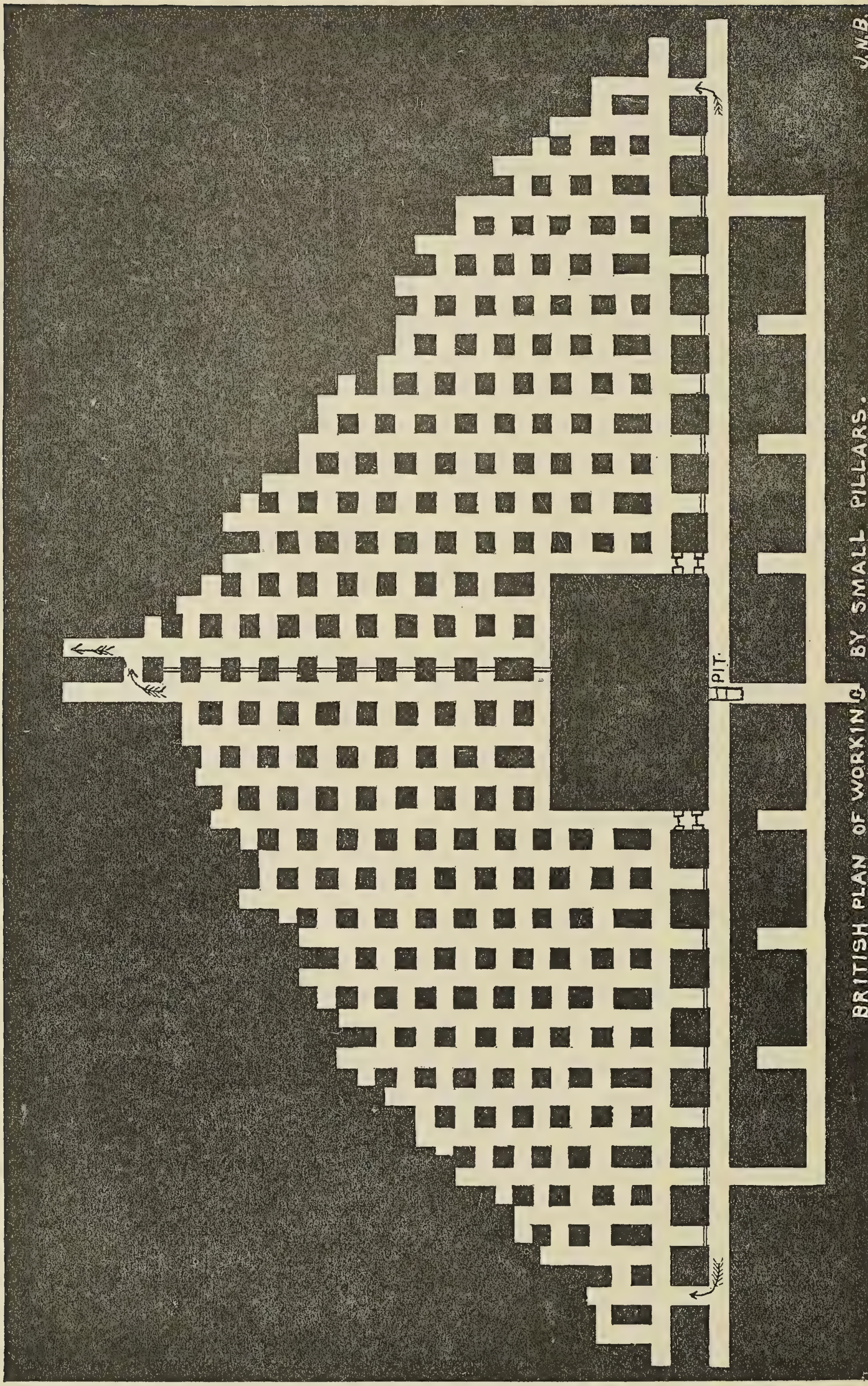
2. If the roof contains water, the letting down of which would spoil the tram-ways or overpower the engine and pumps.

3. If the coal be so near the surface that the long-wall workings would have the effect of damaging buildings.

4. If the cuttings of the roof or floor for height are so soft or friable that they would not be sufficient to support the roads, in which case the expense of setting additional props or obtaining other material may exceed the value of the coal, or its cost by another system.

5. If the seam be deep, and from its thinness suitable for long-wall, yet the small quantity ordinarily produceable from one establishment may render its working unprofitable; or, in other words, the maintenance of expensive roads, or the number of pits required, may not be repaid by the working thereof.

In the first system—working by pillars and rooms—the mines are laid off by driving water levels or galleries along the line of strike of the coal from opposite sides of the pit bottom. On the dip-side of the gallery a small quantity of water follows the workman, and serves as a guide in advancing the work. The main part of the workings is driven to the rise of the coal strata, for in British mines the coal measures have generally a well-defined dip and rise. Advantage is taken of the face and butt slips, and the rooms are worked on the face of the coal whenever it is practicable to do so, as the coal is much easier worked on the face than obliquely. Three-fourths of the coal are usually taken out, the remaining fourth being left for pillars. A common practice is to make the rooms of the same width and size of the pillars left; thus, where the rooms and cross-cuts are each fifteen feet wide, the pillars are made fifteen feet square; to add strength to the pillars, they are frequently formed into diagonal blocks, like the black squares of a checker-board. This system is only practicable in shafts of comparative shallow depth, and where the coal, roof and floor are alike hard, firm and compact. Under other conditions a crush or creep of the workings is sure to follow, before the domain sought to be won is half wrought over. This plan is now rarely practiced in British mining, and will soon disappear altogether. Its advantages consist in



BRITISH PLAN OF WORKING BY SMALL PILLARS.

less narrow work than obtains in the other systems of mining, and as narrow work always adds to the cost of coal mining, it is the cheapest way of working out a mine. As 75 per cent. of the coal is recovered in working forward, the pillars are abandoned when the rooms are all worked out. Under this system the recovery of the pillars is impracticable.

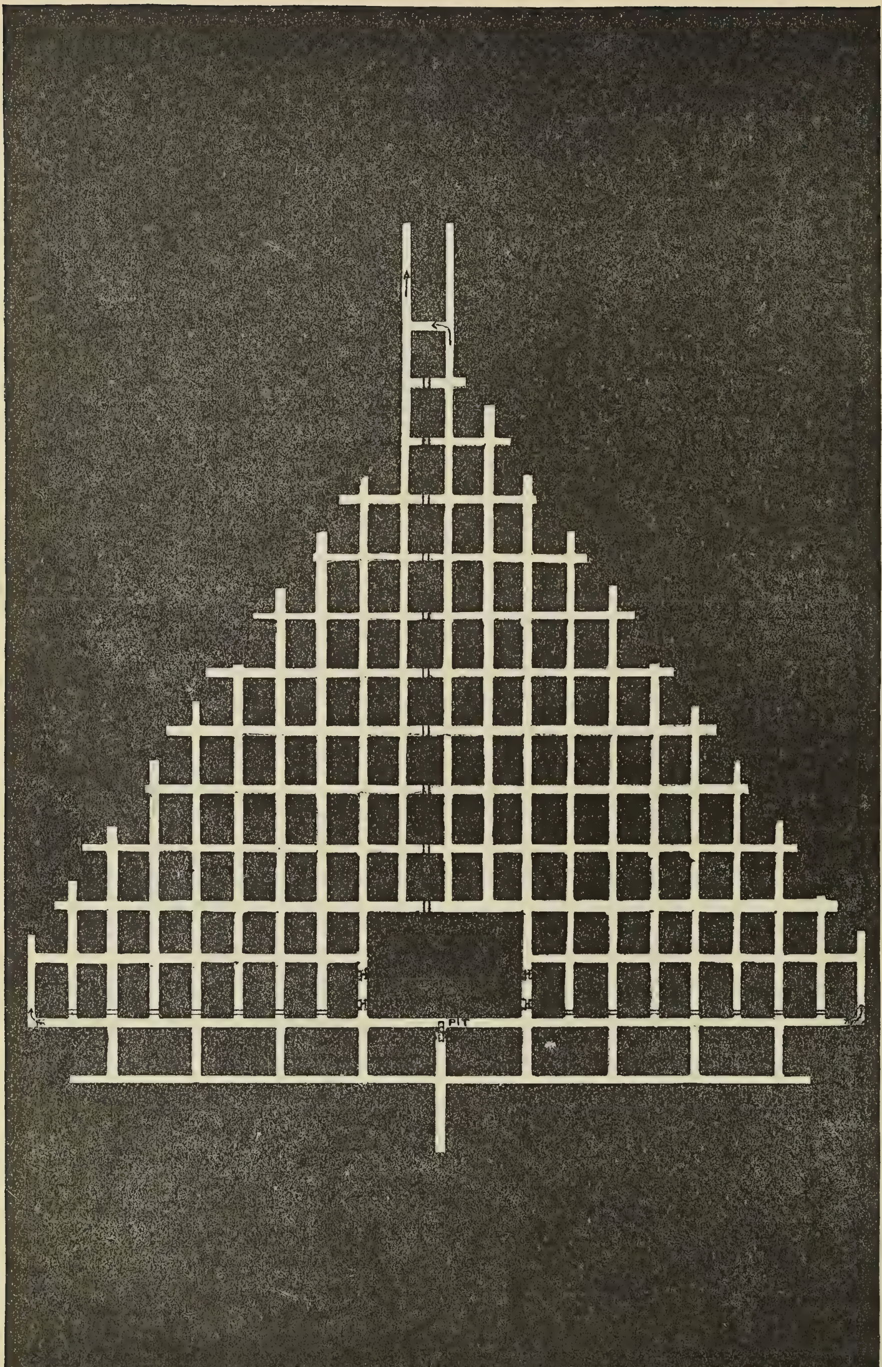
The deeper pits are sunk, the greater the pressure upon the underground workings; hence, in the second system, which prevails in the deeper mining districts, the amount of pillar coal left under ordinary conditions is proportioned to the depth of the shaft.

In the following table, in which the rooms are supposed to be fifteen feet wide, and the air-way six feet wide, the increasing thickness of pillars is proportioned to the depth of the mine:

Feet of depth.	Size of pillars, in feet.	Proportion in pillars.
120	60x15	41 per cent.
240	60x18	50 "
360	66x21	52 "
480	66x24	57 "
600	66x27	59 "
720	66x36	61 "
840	78x42	63 "
960	78x45	66 "
1080	78x48	69 "
1200	84x51	71 "
1320	84x54	73 "
1440	84x60	75 "
1560	90x63	77 "
1680	90x67½	78 "
1800	90x72	79 "

The above table is, of course, general rather than specific, for there may be other conditions which determine to a considerable extent the width of rooms and size of pillars, as, for example, the nature of the floor as to its hardness and softness as well as the depth of its softness, the nature of the coal as to texture and hardness, and the character of the face and butt slips of the mine; also, the nature of the roof of the mine, whether compact and firm, or loose and soft.

After the rooms are all worked out by the system of leaving strong pillars, the pillars are attacked at the far end of the mine and worked back, the miners retreating under cover of the remaining pillars. When the excavated area begins to crush and fall down, part of the pillar coal



BRITISH PLAN OF WORKING BY PILLARS OF EXTRA STRENGTH.

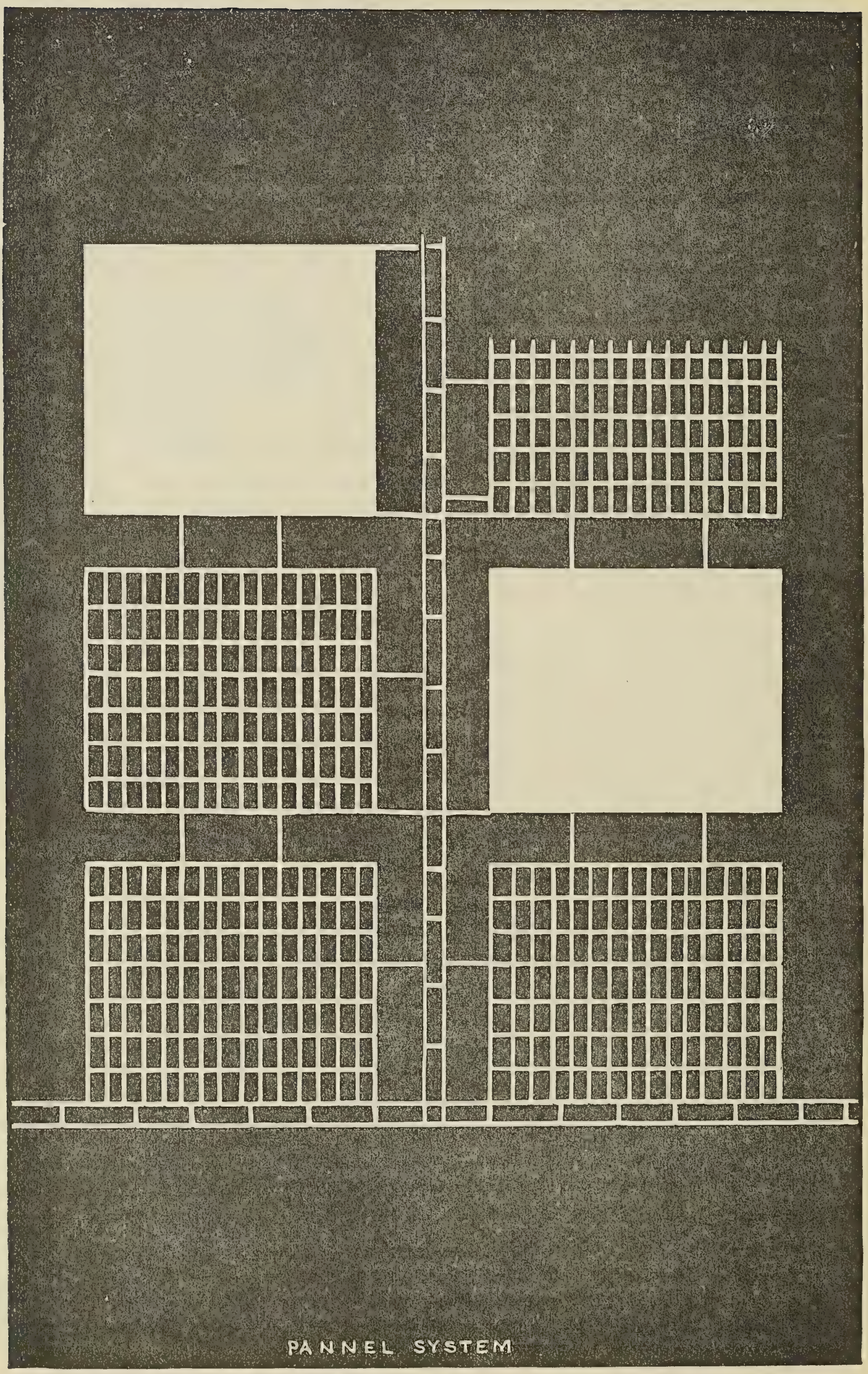
is lost by the massive falls of overlying strata, though, under favorable conditions ninety per cent. of the whole seam is recovered; generally, however, not more than 70 to 80 per cent of the whole is won. A rule of mining engineers in computing the yield of solid coal in the mine, is 1,000 tons to the acre for every foot of thickness; this is 62 per cent.; but in this calculation allowance is made for slack, which is not unmerchantable, and which frequently amounts from 12 to 15 per cent. of the whole.

In the third system, which was devised by John Buddle, to whom the British nation is indebted for a number of important improvements in the art of mining, the pillars may be removed at any time. By this system, instead of carrying forward the workings to the boundary of the mining property before attacking the pillars, the mine is laid out in a series of quadrangular panels; each panel covering 10 or 12 acres of land, and including from 16 to 25 rooms. On all sides of the panel a solid wall or pillar of coal is left, varying in thickness according to the resisting power of the coal and floor of the mine. Air-ways and hauling-roads are cut through the panel walls at proper distances, the rooms being opened from an inner parallel gallery, and carried forward on the face or rise of the coal until the back end of the panel is reached; the pillars are then attacked and withdrawn, and the superincumbent strata of the excavated area are allowed to fall and close in.

While the work of withdrawing pillars is going on in one panel the rooms of an adjoining panel are advancing forward, the strong and solid pillars surrounding the excavated panel resist the crush, and confine it at home.

The following interesting description of this system of working, taken from Ure's Dictionary of Arts, Manufactures and Mines, explains in detail the manner of panel working, as devised by Mr. Buddle in the New Castle coal field in the north of England:

"By this plan of Mr. Buddle, the pillars of a panel may be worked out at any time most suitable for the economy of the mining operations, whereas, formerly, though the size of the pillars and general arrangements of the mine were made with the view of taking out ultimately a great proportion of the pillars, yet it frequently happened that before the workings were pushed to the proposed extent, some part of the mine gave way, and produced a crush; but the most common misfortune was the pillars sinking into the pavement, and deranging the whole



PANNEL SYSTEM

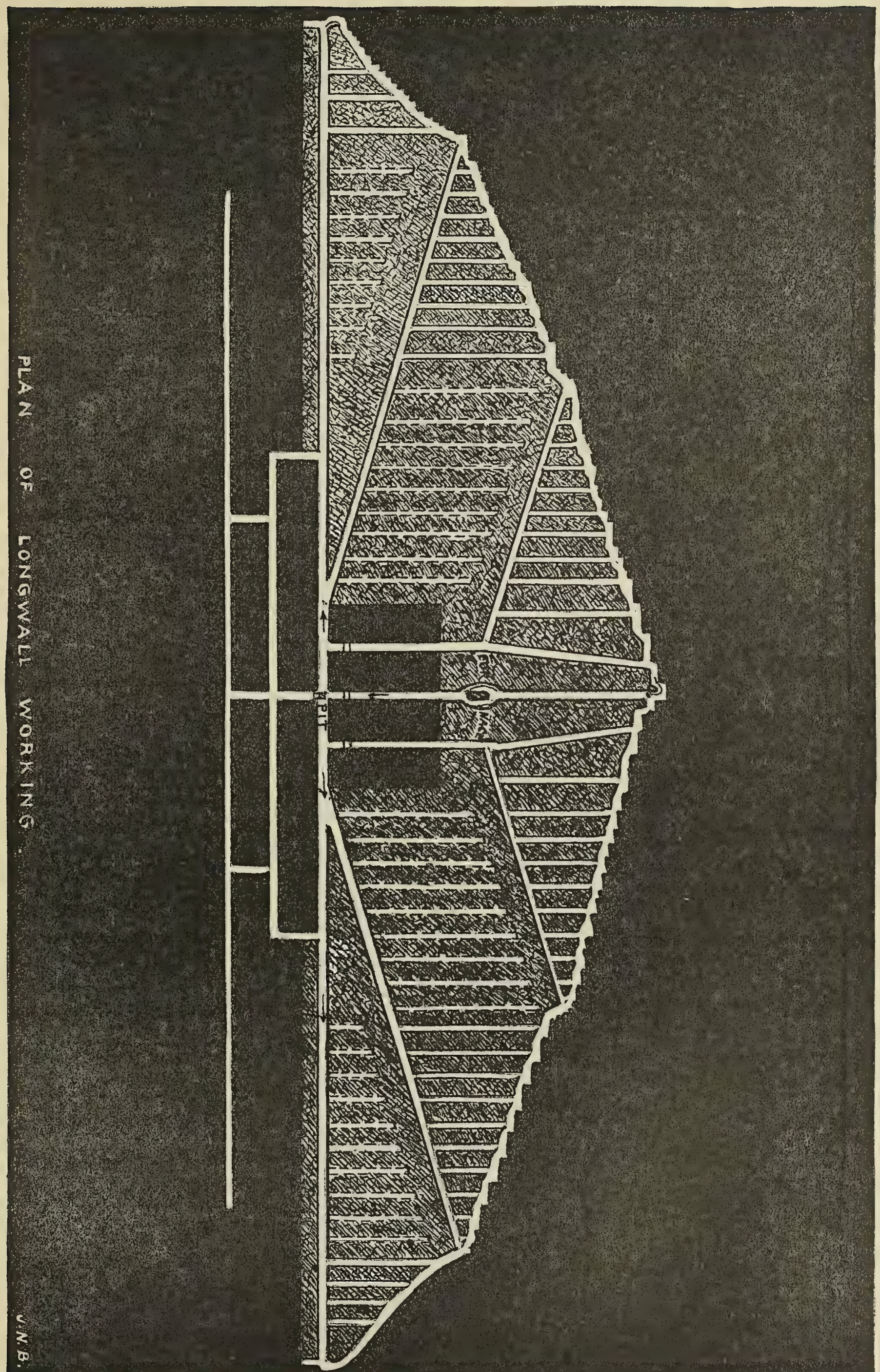
economy of the field. Indeed, the crush or creep often overran the whole of the pillars, and was resisted only by the entire body of coal at the wall faces, so that the ventilation was entirely destroyed, the roads leading from the wall faces to the pit bottom shut up, and rendered useless, and the recovery of the colliery by means of new air-courses, new roads, and by opening up the wall faces or rooms, was attended by prodigious labor and expense. Even when the pillars stood well, the old method was attended with other very great inconveniences. If water broke out in any particular spot of the colliery, it was quite impossible to arrest its progress to the engine pit, and if the ventilation was thereby obstructed, no idea could be formed where the cause might be found, there being instances of no less than thirty miles of air-courses in one colliery. And if, from obstructed ventilation, an explosion of fire-damp occurred while many workmen were occupied along the extended wall faces, it was not possible to determine where the disaster had taken place, nor could the viewers and managers know where to bring relief to the mutilated and forlorn sufferers.

In Mr. Buddle's system, all these evils are guarded against, as far as human science and foresight can go. He makes the pillars very large, and the rooms or boards very narrow, the pillars being in general cases, twelve yards broad and twenty-four yards long, the boards four yards wide, and the walls or thirlings cut through the pillars from one board to another, only five feet wide, for the purpose of ventilation. When the pillars of a panel are to be worked, one range of the pillars is first attacked, and as the workmen cut away the furthest pillars, columns of prop-work are erected betwixt the pavement und the roof, within a few feet of each other, till an area of about one hundred square yards is clear and without pillars, presenting a body of strata perhaps one hundred and thirty fathoms thick, suspended clear and without support, except at the line of the surrounding pillars. This operation is termed "working the goaf." The only use of the prop-work is to prevent the seam, which forms the ceiling over the workmen's heads, from falling down and killing them by its splintering fragments. Experience has proved, that before proceeding to take away another set of pillars, it is necessary to allow the last made goaf to fall. The workmen then begin to drive out the prods, which is the most hazardous employment. They begin at the more remote props, and knock them down one after another, retreating quickly under the protection of the remaining props.

Meanwhile, the roof stratum begins to break by the sides of the pillars and fall down in immense pieces, while the workmen still persevere, boldly drawing and retreating, till every prop is removed. Should any props be so firmly fixed by the top pressure that they will not give way to the blows of heavy mauls, they are cut through with axes, the workmen making it a point of honor to leave not a single prop in the goaf. The miners next proceed to cut away the pillars nearest to the sides of the goaf, setting prop-work, then driving it and returning as before, until every panel is removed, excepting small portions of pillars which require to be left under dangerous stones to protect the retreat of the workmen. While this operation is going forward and the goaf extending, the superincumbent strata being exposed without support over a large area, break progressively higher up, and where strong beds of sandstone are thus giving way, the noise of the rending rocks is very peculiar, at one time loud and sharp, at another, hollow and deep.

The fourth or long-wall system, by which all the coal is mined out as the workings progress, is the best method of working coal wherever the conditions are adapted to this manner of mining. Seams from 4 feet downward are best suited for long-wall working, but in addition the coal requires to be tolerably hard and firm, so as to bear the pressure of the overlying strata. The roof requires to be comparatively free from water, and an ordinary amount of refuse or waste material must be at command in the mine to make the system a success. Beds of coal which have bands of shale running through the body of the coal, or have a falling or draw shale for a roof, are best adapted for long-wall, this material serving for building packwalls or filling up the gob.

In laying out the workings of a mine on the long-wall system, the coal left underground is a strong square pillar surrounding the bottom of the pit, to preserve the shaft from becoming involved in the breaking of the overlying strata which follows the removal of the coal. The main galleries of the mine are then advanced along the line of strike of the seam, and the walls or working faces are opened out from the entry, one working-place following another, like troops marching in echelon. Where the conditions are suitable, the walls are opened out in all directions and the workings advanced in the form of an ellipse. The wall-faces, which vary in width according to the surrounding conditions, are undermined across their whole width by the workmen before leaving



PLAN OF LONGWALL WORKING.

the mine in the afternoon, and during the night the weight of the overlying strata breaks down the coal, which falls forward on a range of sprags planted for the purpose by the miners. In some mines there is a wall-face from three to four hundred yards in length, extended in a straight line, and sometimes a line of face is formed like the arc of a circle.

As by this method of mining, artificial pillars must be erected to prevent the closing in of the workings, consequent on the removal of all the coal, skill and judgment are required in building pack-walls and maintaining roads. The pack-walls are built on each side of the hauling roads, from the debris of the seam or from the cuttings of the roof or bottom. In some mines, where suitable material does not exist underground for building purposes, it is brought down from the surface, but this adds materially to the cost of mining.

This system of working is largely followed in Scotland, fifty-five per cent. of the coal of that country being mined on the long-wall plan. In the central counties of England the thin seams are nearly all worked in this manner, and in Somersetshire beds of coal only 13 inches in thickness are worked by long-wall. In South Wales the system is in high favor. In Belgium and Saxony, on the continent of Europe, long-wall mining is also extensively followed.

While the long-wall system is mainly confined to seams of ordinary thickness, it is capable of more general application than is generally believed. It has been successfully applied to the great thick coal of South Staffordshire, which ranges from 21 to 36 feet in height; the coal is mined in several lifts, beginning at the top, and is worked away in long sweeping sides of working-courses, which range from 3 to 6 feet in thickness. After the first lift of workings is finished, a second or lower lift is opened out by driving forward a new set of galleries and opening out a new range of walls, and so on.

By the long-wall system nearly all the coal mined is round or lump, 14 per cent. of slack being made by pillar and room-working, against 3 per cent. by long-wall, and the ventilation is also simple, there being but one main air course in the interior of the mine at the wall-face. In addition also to the greater acreage of coal recovered by this system, the expense of getting the coal is materially reduced; but additional care and skill are required in the management of mines.

The Ohio Coal Field.

The great Appalachian Coal Field, the largest known coal field in the world, of which the Coal Measures of Ohio constitute a part, extends through portions of nine different States, viz., Pennsylvania, Maryland, West Virginia, Virginia, Kentucky, Ohio, Tennessee, Alabama, and Georgia, and occupies an area which has been variously estimated at from 50,000 to 58,000 square miles. From 10,000 to 12,000 square miles of this area are situated in Ohio. More than one-fourth of the State is therefore underlain with coal bearing strata. The western margin of the Ohio portion of the great coal field runs through the counties of Trumbull, Geauga, Portage, Summit, Medina, Wayne, Holmes, Knox, Licking, Perry, Hocking, Vinton, Jackson, Pike, and Scioto, and the Coal Measures are spread over all the territory lying east of this line of outcrop to the state line at the Ohio river.

On the margin of the Coal Measures of Ohio in the above named counties, there is only one workable vein of coal met—the lower seam, or Coal No. 1 of the geological nomenclature; and owing to the peculiar conditions under which this coal was formed, it is often wanting where the practical miner, unacquainted with the peculiar irregularities under which the coal was deposited, would unhesitatingly assert its existence. The coal strata dip at the rate of about 30 feet to the mile, in an easterly direction (the line of dip being south 65 east), and the lower coal which crops out on the western flank of the coal measures of the State is carried 1,500 to 1,600 feet below the highlands in the counties of Belmont, Monroe, Washington, and Meigs, on the Ohio river. The dip of the strata is irregular, being at some points as high as 80 or 100 feet to the mile, while at other points it is not more than 10 or 20 feet to the mile. Frequently reverse dips are met, causing the strata to form a series of synclinal and anticlinal waves.

The Coal Measures of the State are divided into 3 series, namely: "The Lower Measures, the Barren Measures, and the Upper Measures." The lower measures are about 500 feet in thickness, the barren measures 400 to 500 feet, and the upper measures 600 feet thick. All the beds of coal in present course of development are drawn from the upper or lower coal measures, the barren measures, as the name indicates, containing little coal of sufficient thickness for the immediate purposes of the miner.

The coals now being worked are mainly drawn from four or five

different seams, Nos. 1, 2, 6, 7 and 8 of the geological nomenclature. In mining districts, however, the coals are known by other names than numerals, as, for example, the Brier Hill coal, the Massillon coal, the Nelsonville coal and the Ohio River coal, and so on, and so they will ever be known; these names indicating the districts from which the coals are mined, and giving them a commercial value which dealers easily comprehend.

The coal beds in their progress through the coal area are very changeable in their character and thickness. Thus, the Brier Hill coal is one of the purest and best seams in the State; while the Mineral Ridge coal, although geologically the same bed as the Brier Hill, and separated from the Brier Hill not more than one mile, differs greatly in its chief properties and adaptability for various uses, and is greatly inferior in quality, the Brier Hill coal being a long grained block coal, hard, firm, compact, a homogeneous bed, and adapted for furnace use in a raw state; while the Mineral Ridge variety is a short grained, friable, tender coal, and totally unfit for furnace use. It is also divided into two benches by a band of shale from 1 to 4 feet in thickness, upon which rests a stratum of blackband ore from 1 inch to 1 foot in thickness.

The Development of Coal Mining in Ohio.

The existence of coal in Ohio was noted by the early frontiersmen and by travelers from the time of the earliest settlements. In 1755 a seam of coal was discovered on fire near Bolivar, in Tuscarawas county. A map of the western country, now in possession of Judge T. H. Ewing, of Lancaster, published in the year 1788, notes several sections of iron ore beds, and Harris, in his tour in 1803, states that on the banks of the Hockhocking, "quarries of excellent free stone, beds of pit coal, iron ore, lead, strata of white and blue clay of excellent quality, red bole, and many other useful fossils are found."

Some of the pioneer miners of the State still survive. Coal was mined by stripping near the village of Talmadge, in Summit county, as early as 1810. Mr. Asaph Whittlesey, father of Col. Chas. Whittlesey, of Cleveland, and Mr. Henry Newberry, father of Dr. J. S. Newberry, were the pioneer miners of Eastern Ohio, and Col. Whittlesey has published a very interesting account of the discovery and development of the coals of that part of the State. The first mines opened by

drifting in this region were operated by Messrs. Asaph Whittlesey and Samuel Newton in the year 1820, the coal being sold exclusively for blacksmithing purposes. In 1818 the first shipments were made to Cleveland, from the mines of Mr. Henry Newberry, with the object of supplying the lake steam-boats with coal, but wood was so abundant and cheap that the coal found little sale. In noting this fact in my fourth annual report, as Inspector of Mines (1877), I received the following letter from Mr. H. V. Bronson, of Peninsula, Summit county, who took the first boat-load of coal to Cleveland :

PENINSULA, SUMMIT COUNTY, OHIO, *April* 8, 1878.

ANDREW ROY, ESQ.:

SIR: Not long since I saw in the papers that in your annual report, as State Inspector of Mines, that the first coal shipped by canal to Cleveland was in the year 1828, and by the late Mr. Henry Newberry, of Cuyahoga Falls, father of Professor Newberry, of Cleveland. I took that coal to Cleveland for Mr. Newberry, it being 50 years ago since it was done. I was then in the seventeenth year of my age, and have resided in this place ever since 1824. There were three of us boys on the boat. One of them was about a year my junior, and now resides in one of the townships of Cuyahoga county, and became a successful inventor and business man. The other one was then in the twelfth year of his age, and is now a lawyer with a lucrative practice, in a beautiful growing city in an adjoining State. On the first day of January last, I made a New Year's call on Prof. Newberry, at his home in Cleveland. A few years ago I presented Prof. Newberry with a lump of the coal taken from one of the boat-loads of that coal. As this whole transaction is somewhat remarkable, I have taken the liberty to write you about it, especially as we three boatmen are natives of Cuyahoga county.

Yours, respectfully,

H. V. BRONSON.

The Talmadge Coal Company was organized in 1838, and opened mines on Coal Hill, from which most of the coal was mined for the Cleveland market, until the year 1845. The coal on the property of this company was discovered by Mr. H. F. Wright, in 1825, while digging a ground-hog out from under a stump. The first working was done by stripping the vein, and quarrying it out with pick axes. In 1832 the Ohio Canal reached the coal fields near Massillon, and the mines of this region were opened by Cyrus Mendenhall. In 1845 David Tod, afterwards Governor of Ohio, commenced shipping by canal from the mines of Brier Hill to Cleveland.

The late President Garfield was, in early youth, a canal boat driver from the mines of Gov. David Tod, at Brier Hill, to Cleveland. He

was then 15 years of age, and had already given evidence of earnestness of character and a desire to obtain an education. Gov. David Tod told the writer of this article, that after the Brier Hill coal was fairly introduced in the Cleveland market, the demand for it was so great that he could not supply orders, and was urged to load a boat on Sunday. He went down to the canal to consult the boatmen on the subject. All the employes of the boat, except young Garfield, were engaged playing cards, while the driver boy was found on the front of the boat, alone, intently studying a history of the United States. Garfield's name was not in that history, added Gov. Tod, but the future student of American history will find it there.

The first coal mined at Mineral Ridge occurred in the year 1835, the mines being opened at Coal Run, on the land of Michael Ohl. In 1833 Roger Hill, a Pennsylvanian, who had formerly mined coal in Beaver county, of that State, moved to Mineral Ridge. He pointed out a coal bed to Mr. Ohl, which, on being opened, proved to be 4 feet thick. Hill, who was employed to open the mine, in drifting into the hill, selected a square and heavy piece of the mineral, which differed in weight and appearance from the body of the seam, and carried it home to test its qualities. The piece refused to burn, and was pronounced bastard cannel, or black stone. It was afterward left unwrought in the mine, forming the floor of the excavations. The main part of the coal found ready sale for blacksmithing and domestic purposes, and in 1857 the first shipments were made to Cleveland.

In 1854 John Lewis, an English miner, who had mined blackband ore in the old country, settled at Mineral Ridge. One day, while digging up the floor of his room to set a prop, he was struck with the similarity of the floor to the blackband ore in Victoria mines, in England. He informed the proprietors of the mine, Messrs. Ward & Co., that the floor of the mine was a deposit of blackband ore. The proprietors directed the English miner to mine and calcine some of the ore, which was done with promising results. All the workings were now reopened, and the blackband mined out. The stratum of ore ranged in thickness from 1 inch to 1 foot, and after being calcined yielded 50 per cent. of iron. Several years elapsed before the full value of this discovery was appreciated; the art of calcining the ore, and mixing it judiciously not being properly understood. In 1868 the pig iron, made from a judicious mixture of the blackband and Lake Superior ores, pro-

duced an iron which was eagerly sought for, and since that time pig iron of the Mahoning Valley has taken the front rank in market, being known and prized as "American Scotch."

The first iron manufactured from raw coal in the United States took place at the Clay Furnace, in the Shenango Valley, on the Pennsylvania side of the State line, in the year 1845, and in the following year Messrs. Wilkinson, Wilkes & Co. built a furnace at Lowell, Mahoning county, Ohio, and used raw coal. Messrs. Wilkinson, Wilkes & Co. contended with the projectors of the Clay furnace for priority in the use of raw coal, but this honor undoubtedly belongs to the owners of the Clay furnace in Pennsylvania.

The first furnace built in the Hanging Rock region was erected in Greenup county, Kentucky, in the year 1815, and was called the Argilite. This was followed by the construction of the Vesuvius, Hecla, Lawrence and Mt. Vernon furnaces, on the Ohio side of the river. These were all cold blast furnaces, and the cold air in several cases was blown through hollow gum logs. The products of the furnaces were cast into salt kettles, coal stoves, and kitchen utensils. The forges were run by water power, and the iron was hammered, instead of being rolled into merchant bar.

In the Hocking Valley region the iron industry dates from 1851, in which year Hocking furnace was built, which was followed by the Logan furnace in 1853, and by the Union furnace in 1855. These were all cold blast charcoal furnaces, and used the native block ores of the Hocking Valley. Mr. Samuel Baird built the first stone coal furnace in this valley in 1875, three miles north of the village of Gore, in Hocking county.

The development of the coal mines of the Hocking Valley began with the construction of the Hocking branch of the Ohio Canal. The beds of coal of this region laid bare along the swift moving streams, by the action of water, were noted by the first white settlers who penetrated this region, and coal was mined for domestic uses, and for blacksmithing purposes from the time of settlement of the Hocking Valley. In 1831 the salt business, which began to assume importance a few miles above the village of Athens, gave the coal trade some impetus. In 1832 that part of the Ohio Canal, known as the "Side Cut," was completed to Nelsonville, and coal was shipped from the mines there to Columbus in

September of that year. The late Thomas Ewing was one of a firm who opened the first mines at Nelsonville, the mines being located on the Dover Run canal basin. Only the lower 4 feet of the coal bed was mined, the upper bench being left for a roof. Twenty years afterward this mine was reopened, and the top coal, abandoned by the first workers, was taken down and sold. C. Fay, John Carruthers, C. and L. Steenrod, and J. F. Somers were among the pioneer miners of the Hocking Valley. The best market for coal in those early days was Newark, Ohio. Among the early buyers in Columbus were John L. Gill, and the old Neil House.

Coal was first mined in a systematic manner on the Ohio river, below Wheeling, in the year 1833. Samuel Wyllis Pomeroy, of Boston, Mass., purchased the lands on which the Pomeroy mines are now opened, in 1803. In 1818, with the view of opening the mines, he wrote to a merchant in Cincinnati to ascertain the consumption of coal between his property at Pomeroy and the Falls of the Ohio river. He received the following reply:

I am able to communicate to you the following information:

	Bushels.
Cincinnati Steam Mill consumes annually	12,000
Iron Foundry " "	20,000
Steam Saw Mill " "	5,000
Manufacturing Co. " "	5,000
Sugar Manufacturing Co. " "	2,000
Amount	44,000
In Maysville, or Limestone, used or sold	30,000
In Louisville, used or sold	30,000
Madison Mill (140 miles below Cincinnati)	12,000
Total	116,000

Coal was not used for domestic purposes in the towns of the Ohio river until the year 1833. A steam tow-boat, named the Condor, built by the Pomeroy Coal Co., in 1835, was the first tow-boat on the Ohio river. She took the loaded coal boats to Cincinnati and brought back the empty boats to the mines at Pomeroy The Lake Erie, built at Pittsburgh in 1837, followed the Condor.

The shaft coal at Steubenville was discovered in the year 1829 by Adam Wise, while boring a hole for water for the supply of one of the village manufactories. The coal was met at a depth of 225 feet below

the surface, and was pronounced to be 11 feet thick. As the Pittsburgh vein was found in the hills surrounding the village, the idea of sinking a shaft to such a depth was not conceived for many years afterwards. In 1856, however, Mr. James Wallace, proprietor of the Ashland Woolen Mills, began agitating the question of sinking a shaft in the city of Steubenville, the hill banks, owing to the horrible condition of the roads during muddy weather, being unable to furnish the manufacturing establishments a steady supply of coal, and a mining company was soon organized, with Mr. Wallace as president.

Before commencing sinking, it was deemed prudent to drill another hole to the coal, to test the accuracy of the former borings; this time the coal was pronounced 8 feet thick. The shaft was laid out at the upper end of Market street, and the work of sinking began. Coal was struck in the fall of 1857, but instead of 8 feet it was was found to be less than 4 feet. The projectors were greatly discouraged in consequence, but decided to go on with the enterprise. In the following year, Messrs. Boreland, Reynolds and Manful leased the mine for five years, and fitted up the shaft with hoisting machinery and other needed apparatus, and the work of mining was begun. Fortunately for the lessees of the mine who were without former experience in mining, they soon afterwards secured as manager of the works Mr. William Everick, a first-class practical mining engineer from the Midlothian coal fields of Virginia. The enterprise which languished until Mr. Everick assumed charge, was now a success. The superior quality of the coal for every purpose, but especially for making gas and smelting iron, at once established its reputation, and other similar enterprises were inaugurated. This shaft is still in operation, and is known as the Market Street Shaft; the underground department is under the management of Mr. Wm. Smurthwaite, one of the best practical miners in the State.

There are two seams of coal quite extensively mined in Jackson county—the Jackson coal and the Wellston or Coalton coal. The Jackson coal, which is the lower bed of the State series, was discovered in 1863, by a party of drillers while boring for salt. The coal from this seam is mainly used in the blast furnaces of the county. The Wellston coal was discovered in 1872 by Hon. H. S. Bundy, while exploring for the shaft coal of Jackson, on the lands on which the village of Wellston is now built.

The Milton Furnace and Coal Company sunk the first shaft to the

Wellston coal in 1873. This was followed in 1874 by a shaft owned by the Wellston Coal and Iron Co. For some time after the discovery of this coal there was considerable diversity of opinion as to whether the Jackson and Wellston coals were equivalent, but the question was settled in 1877.

Two narrow-gauge railroads were projected to the Jackson county coal field in 1876—the Springfield, Jackson and Pomeroy Railroad and the Dayton and Southeastern Railroad. The Springfield, Jackson and Pomeroy road was projected to reach the Jackson shaft coal, and the Dayton and Southeastern the Coalton coal. The Springfield road was completed to Jackson in the early part of 1878, but the superiority of the Coalton coal for domestic purposes and for generating steam was so marked that a branch road was at once run up Horse Creek from Jackson, to strike the Coalton seam, 5 miles north of Jackson.

The mines at Coalton were opened in the fall of 1878, and shipments of coal began at once. The Springfield road was, however, in the fall changed to a standard gauge, and little shipping was done before winter. It is now known as the Ohio Southern Railroad.

In the spring of 1880 the Dayton road was finished to Wellston, the two lines meeting at Coalton, making a second outlet for the coal. A dozen mines were opened, and a mining village built, as if by magic, and what was two years ago a rough and poor agricultural country, sparsely settled, was filled up by a new population, who sought and found treasures in the bowels of the earth. The Dayton and Southeastern road is now part of the Toledo, Cincinnati and St. Louis road.

The coal out-put of the county, which in 1873 did not exceed 60,000 tons, in 1880 exceeded 200,000 tons, and in 1882, 350,000 tons.

A brief sketch of the early development of all the mining districts of the State would make an interesting paper, but would be too long for the space allotted to this chapter.

Conditions of Coal Mining in Ohio.

The beds of coal which traverse the Ohio coal field are not disturbed by dykes or dislocations of the strata, so frequently found in other coal fields of the world. There are many local faults found in our coal mines, which are known by the general name of "horsebacks." These faults, which sometimes come from the roof and sometimes from the floor of the mine, are occasionally troublesome and expensive; but tak-

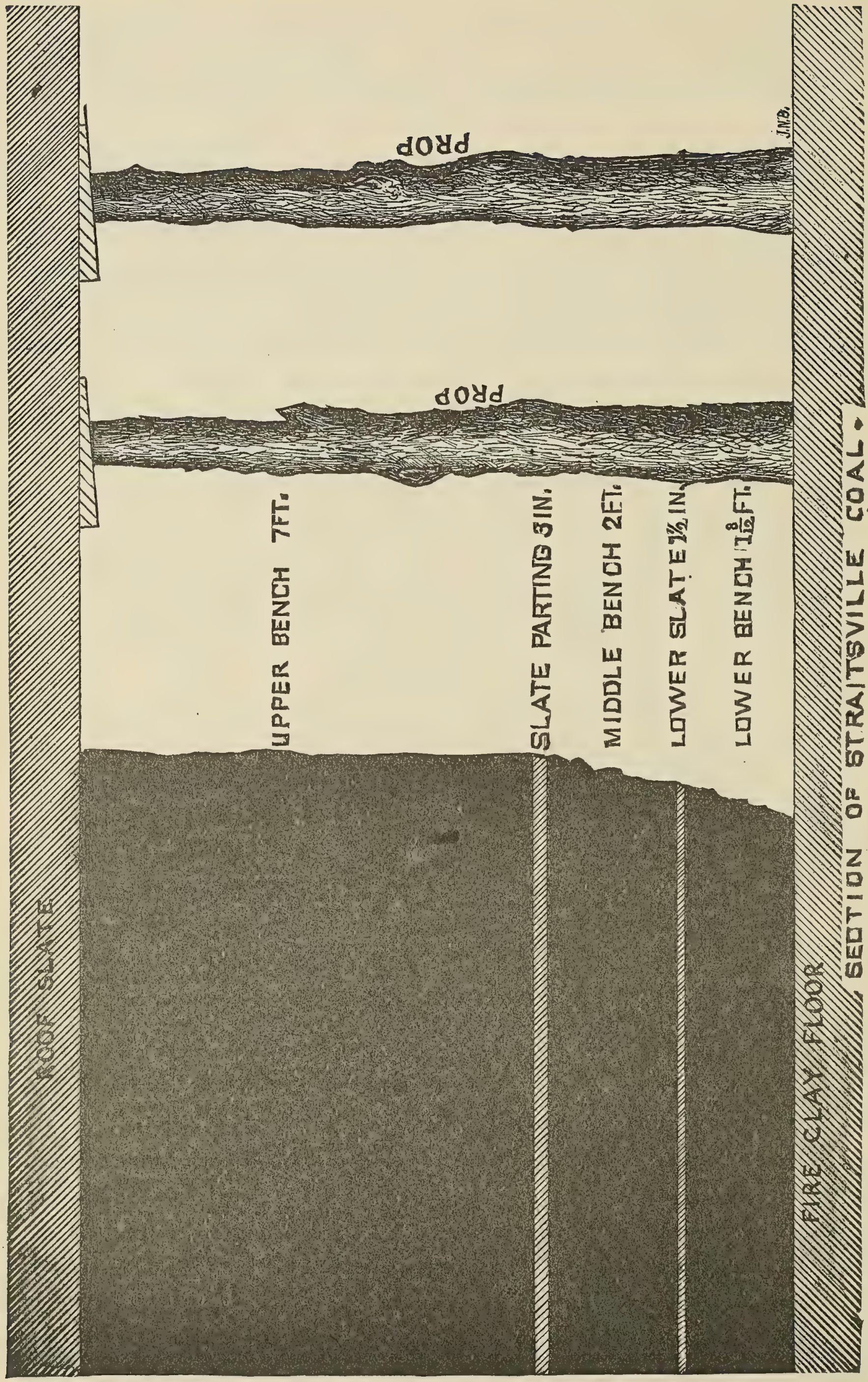
ing the whole coal field throughout, the conditions for cheap and systematic mining are unusually favorable. The floor of mines is comparatively level, the usual dip, except in local cases, being 25 or 30 feet to the mile.

Over large areas of the coal field, where the country is hilly, the beds of coal in course of development come to day or crop out in the hillsides, and admit of what is termed drift or level-free mining. Under such conditions the seam is followed into the hill, and the waters of the mine discharge themselves by gravitation. Care is taken in opening a drift mine to select the lowest place on the property, if the circumstances will admit of it.

In regions where level-free mining is impracticable, two methods of sinking for coal are followed: one is by opening perpendicular shafts, and the other by sinking slopes at a pitch of from 25 to 35 degrees. Slopes are, however, rarely opened where the coal is found more than 150 feet below the surface, for below this depth it is more costly to sink and deliver coal by a slope than by a perpendicular shaft. Under favorable conditions slopes are largely a matter of taste on the part of managers; they are never cheaper than shafts.

The coal business has localized itself and the various districts in which the mines are opened are known by appropriate names. There are now a dozen districts in the State in which the coals possess popularities by which they are known, as the Mahoning Valley region, the Jackson County region, the Ironton region, the Pomeroy region, the Bellaire region, the Steubenville region, the Salineville region, the Cambridge region, the Dell Roy region, and the Coshocton region. Sometimes two or more qualities of coal are drawn from the same bed, as, for example, the Brier Hill coal and the Mineral Ridge coal, both of which are mined in the Mahoning Valley, or the Nelsonville, Straitsville, Shawnee, Sunday Creek and Monday Creek coals, all of which are drawn from the great seam of the Hocking Valley region.

All other conditions being equal, the best seams are selected and opened. There are thousands of acres of as good coal still untouched in the coal field as any in present course of development, but for want of railroad facilities, or because of its lying in the interior of the coal field, it remains for the time being unwrought. The severe competition of the trade obliges the mining operators to take advantage of all the conditions in developing the mines. The districts which are furthest



SECTION OF STRAITSVILLE COAL.

from market must have superior coals, which command extra prices, or else the trade languishes. The business largely turns on the character of the individual seams. The quality of the coal rather than its thickness, and the cost of placing the same upon the market, very largely determines the value of mining properties and mines.

All seams of coal, two feet thick and upward, are regarded as of mineable thickness, but four feet is regarded as the standard height. The expense attending the working of a three-feet vein is often considerably greater than working one four feet, exclusive of the dead work. This is a general but not universal rule, and obtains in mines like those of the Mahoning and Tuscarawas Valleys, where the coal varies suddenly in thickness. In such mines, for digging all coal below four feet, 5 cents per ton extra is paid for every 3 inches of decreasing height, until the seam falls to two feet, when it is regarded as unmineable. At Leetonia, Hammondsville, and in the Coalton district of Jackson county, coals no thicker than 28 to 32 inches are wrought, but these coals possess peculiar qualities. The best coke in the State is made at Leetonia and Hammondsville, and everything that comes from the miner's pick is credited to him. At Coalton the coal is tender, and mines very easily. The difference in expense of mining a 4-feet coal over a seam 10 feet in thickness is inconsiderable in amount; the advantages to mining operators who possess thick coals consisting more in the greater yield per acre than the lessened cost of production. Thus, at Wellston, in Jackson county, the coal is 4 feet thick; while at Straitsville the bed is 9 to 10 feet thick, but the same price obtains in both places for digging; at Wellston the coal is a homogeneous mass, while the thick coal of the Hocking Valley contains two bands of shale, and frequently a band of bone coal, which have to be sorted out by the miner, which militates considerably against his producing power.

In point of economy, drift mines do not ordinarily possess any material advantage over shaft mines opened in the same district.

It costs less, it is true, to open and equip a drift than a shaft; but after a shaft is opened and equipped the workings may be extended east, west, north and south, without any interruption to their symmetry or continuity. In drift mines on the other hand, even under the most favorable circumstances, not more than one-half of the same extent of work can be opened up; and, frequently, by means of the numerous avines which cut down through the coal, a symmetrical and extended
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mine cannot be laid out at all. Moreover, a considerable part of hill coal along its line of outcrop is so largely impregnated with iron rust and earthy matter, as to render it unfit for market. In deep shaft mines, which discharge a great flow of water, the advantages are in favor of drift mining, but we have neither deep nor wet mines in Ohio.

The Manner of Mining.

In districts in which coal seams about to be developed are level-free, the manner of opening mines is simple and inexpensive. The coal is usually exposed at some point on the hill-side, and is readily distinguished by a dark colored streak on the clay, called the coal "blossom" or "outcrop." As the blossom is followed into the hill it gradually hardens into coal. For some yards, sometimes for many yards, the coal is soft, dead and rusty. This is called crop coal, and cannot be shipped. If the front of the hill in which the mine is opened is bold and steep, the coal soon becomes compact and bright, and fit for commercial use; but if the hill is retreating, and the mine is opened near the top, the entries may be pushed from 50 to 100 yards before merchantable coal is met. On lands where the cover is light, say 30 or 40 feet, and is mainly composed of alluvial matter, only a few feet of shale forming the immediate cover of the seam, the coal is often so tender and earthy as to be worthless. Under such conditions the roof is never good.

All drift mines require to be timbered for some distance from the mouth. The timbers, which are made out of hewn or sawed wood, are usually 8 by 10 inches in size, their length being governed by the height of the seam. The bents are sometimes placed close together, but are generally set about 2½ to 3 feet apart, the intermediate space being filled with 2-inch plank. The leg of each bent of timbers slants inward about 1 foot in 6. If the bottom of the mine is wet, cross-sills are laid under each bent to keep them from sinking.

The mine is usually made from 8 to 10 feet wide, and the timbering is carried forward until the roof becomes so firm that it will safely stand of its own accord.

The point usually selected for opening is as near the southeast line of the mining property as may be practicable, so as to extend the workings to the north and west, along the rise of the strata, to facilitate hauling and draining, For 100 to 200 feet the coal usually dips from

the mouth of the opening; experienced miners take up several feet of the bottom, which they tail out to a point.

It is not always practicable to open and work to the rise of the strata. The main entries of many mines run east or south. This always adds to the cost of getting the coal, but it cannot be avoided.

When the coal lies in the hill, 25 to 30 feet above the level of the railroad switch, the most favorable conditions for opening a mine are found, as this gives the proper height for dumping the mine cars through the chutes into the railroad cars below. We have, however, to accept the conditions as we find them; and frequently a mine is opened high upon the hill. Under such circumstances an inclined plane is constructed from the chutes to the drift mouth; the track of the plane is made double, the empty train ascending as the loaded train descends.

If, in opening a mine, the coal should be found too near the base of the hill to admit of dumping height, it adds considerably to the cost of hauling, as well as militates against the producing power of the mine to pull the loaded cars up-hill, from the mine mouth to the tipple, by horse-power; under such circumstances it is cheaper in the end to provide steam-power.

When a coal bed lies below water level, and has to be sunk for, it may be reached by a slope or a shaft. A slope dips at from 25 to 30 degrees, and is preferred by many managers to a shaft, owing to the facility it affords for the ingress and egress of the miners. The expense of sinking and equipping a mine with adequate machinery is about the same in a shaft or slope until the latter exceeds 150 yards in length, when, in point of economy, the advantage is on the side of the shaft. In the Mahoning and Tuscarawas valleys the mines opened on the lower bed of the series are generally slope openings. In all the other districts of the State the shaft seems to find favor.

The width of a slope is usually about 10 feet, and the height 5½ to 6 feet. The hauling road or railway track is made single; a loaded train of cars, two or four in number, being first hoisted and then an empty trip lowered. Shafts are made with double hoists, a loaded car ascending in one cage while an empty car descends in the opposite cage. Shafts are rectangnlar in shape and are usually 8 feet wide and 16 feet long.

In commencing to sink, whether by shaft or slope, the horse and gin are employed until solid ground is reached. If the opening be no

greater than 100 feet in depth, the horse and gin is often used until coal is struck, particularly in mines in which the flow of water is not great. It is, however, true economy to erect the permanent hoisting machinery of the mine before ground is broken. This has to be done sooner or later in any event, and it costs no more to construct it one time than another, while the money saved in hoisting rocks and water goes into the pocket of the mining adventurer.

All mines have to be timbered until solid ground is reached. The manner of timbering slopes is similar to that of timbering drifts, except that the bents require to be set a little closer together. In shafts the timbers are laid as tight as possible, and in well regulated mines are made of 10-inch square timbers. In some shallow mines in the State 3-inch plank is used, but this is mistaken economy. Timbers of 8 inches are light enough under any conditions.

The cost of sinking a slope, 10 feet wide, and 6 feet high, does not ordinarily exceed $35 per yard. A shaft 8 feet wide and 16 feet long will average in good ground 45 to 50 dollars per yard. This includes the expense of timbering, the powder used in blasting, and the raising of both rock and water. No uniform rule can, however, be laid down in such matters, the nature of the ground, the flow of water, and the provisions made in commencing operations for the success of the enterprise determine the expense. Some shafts cost more than double that of others under the same conditions, and on the same field the cost of sinking varies greatly, the result of the skill and judgment exercised in grading and directing the subterranean excavations. The machinery of shaft and slope mines consists of an engine for raising coal, a pump for lifting water, and the necessary boiler power. The size of the hoisting engine is in proportion to the depth of the shaft and the weight of the coal raised. Double engines are coming into use around coal mines. Two to four boilers, 36 to 40 feet in length, and of 36 inches diameter, are generally needed to procure the necessary steam power for lifting coal and water. The drums upon which the shaft ropes revolve are 5 to 7 feet in diameter; the pulley wheels upon the pit head-frame of shafts are made 6 or 8 feet in diameter. The hoisting ropes are 1¼ inches in diameter, and are made of iron or steel wire.

At many mines where the coal is met within 100 feet of the surface, less elaborate arrangements suffice, but it is always wisdom to have good, strong machinery, and especially to have abundant steam power.

The money invested for such purposes will surely find its way back into the pocket of the owner of the mines. The hoisting arrangements of slope mines differ somewhat from those of shaft mines; in the former the track is nearly always single, and only one rope is needed, while in shafts the hoist is double. At many slopes a chain is often preferred to a wire rope, but the rope is preferable.

The pit head-frame of shaft mines is made 35 to 40 feet in height; the upper landing, where the coal is delivered, is 22 to 25 feet above the mouth of the pit, and two screens are used in sorting the coal into lump, nut and pea, as it goes from the tipple into the hoppers below.

All mines have water in them. In many drift mines, particularly in those in which the workings extend to the verge of the strata, the water is discharged by gravitation. In slopes and shafts, natural drainage is impossible, and the waters of the mine must be pumped or lifted out by steam power. A number of first class coal pumps are in use in coal mines, Cooper's and Blake's being generally preferred to others. The size of the pump is governed by the amount of water. Some mines discharge much more water than others, and the mines of some districts are wetter than those of others. In the Mahoning Valley more water is met with than elsewhere in the State; this is due to the open character of the coal—the joints of which serve as reservoirs. A favorite pump in this valley, and one still largely in use, is the Buffalo, which has wooden pitmen, which run down the side of the slope. One of the first things necessary after coal has been struck in a slope or shaft mine, is to sink a water lodgment or sump. This is cut in the floor of the coal, and is sunk to a depth of 8 or 10 feet, and made of sufficient diameter to hold several hours' supply of water. A number six steam pump of the Cameron, Cooper, or Blake manufacture will discharge 500 gallons of water per minute, while 200 gallons per minute is a good flow in a mine. The quantity of water in mines varies greatly; frequently two pumps are necessary, sometimes three, and in the Leadville shaft in the Mahoning Valley, six No. 6 steam Cameron pumps were unable to keep down the water, even while the shaft was going down. So great was the flow of water in this shaft that special pumps had to be manufactured expressly for the occasion, and a special shaft sunk along side of the main shaft in order to control the water. More than 3,000 gallons per minute were pumped out of the mine. The history of this shaft is so remarkable that in the description of the

Mahoning Valley district, which will be found in another part of this chapter, a brief sketch of it will be given.

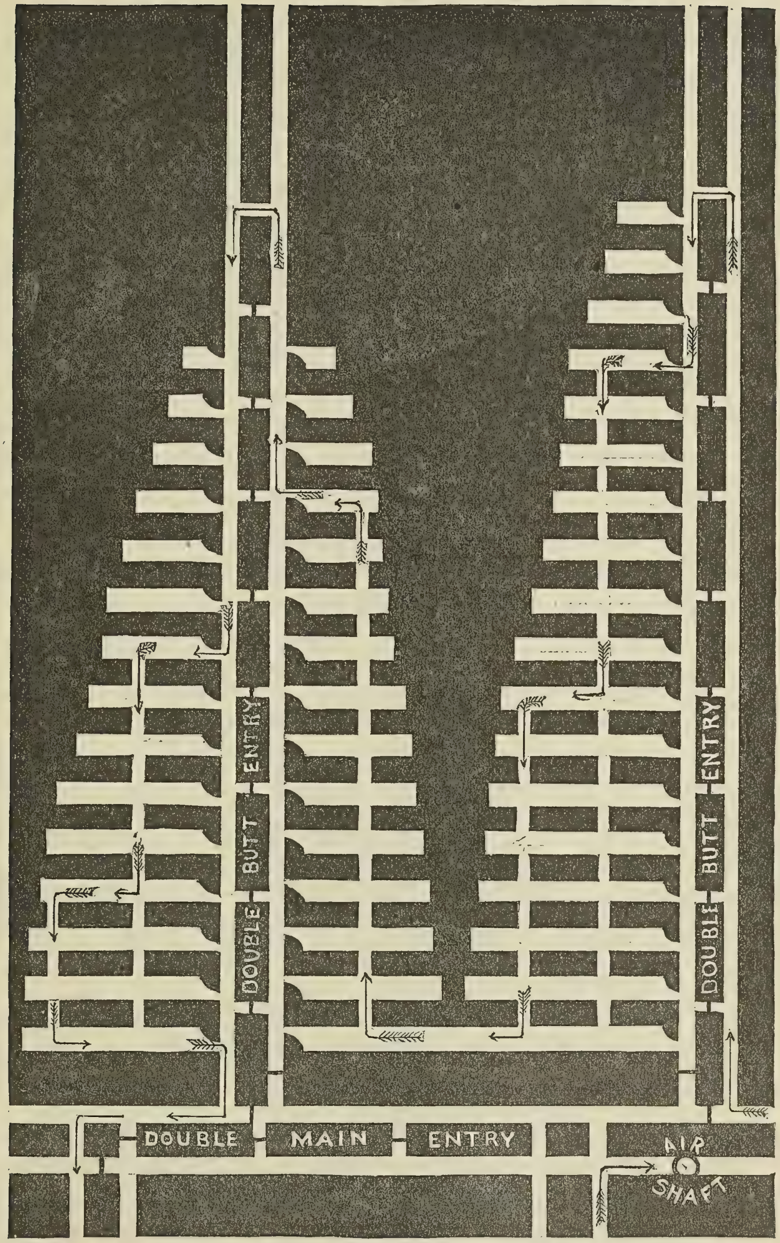
There are a number of methods or systems of laying out the workings of mines in use, according to the varying conditions which are met in the several mining districts, as, for example, the thickness of the overlying strata, the character of the roof as to hardness and softness, the nature and thickness of the underlying fire-clay, the ability of the coal seam to resist pressure, etc. Suitable modifications of all the English systems are practiced, except that of long-wall. A number of mines, situated along the line of the Niles and New Lisbon Railroad were opened out on the long-wall system some years ago, with satisfactory results, but during the late panic, operations were suspended. On resuming work two or three years ago, the mining proprietors changed hands, and the new manager changed the plan to pillar and room practice.

A large amount of coal has been lost, and some valuable coal is still being lost by faulty systems of mining. The first mines opened in the State were drift workings, opened in hills along the lines of outcrop of the coal. These hills, penetrated in all directions with ravines, generally contained only a few acres of coal, and the overlying strata were not heavy. Very light pillars sufficed to support the roof under such circumstances.

As the coal trade began to develop, and the mines became more extensive, the frail supports, which sufficed for small mines, were found inadequate for those of larger extent. The result was the falling in of the workings before they were fairly opened out. In reopening them larger pillars were left; this, however, was done grudgingly, for the larger the pillars left, the greater is the expense of getting the coal. Coal lands were, however, abundant and cheap, and the cost of opening new mines was inconsiderable; hence, there was a temptation to adopt any system which would reduce the immediate cost of working to a minimum.

When shaft mining became a necessity, and the first ton of coal cost the mining adventurers ten or twelve thousand dollars, better systems were adopted from a sense of true economy, until by degrees, in all the mining districts of the State, improved systems were adopted; though there are still mines in every district very unskillfully managed.

In all our well-regulated mines the plans which generally obtain,



PLAN OF WORKING BY DOUBLE ENTRY.

correspond to the second system of British practice—that of working with pillars and rooms, the pillars left being of sufficient strength to maintain the incumbent strata in place as the workings advanced

and after the rooms are all finished, the pillars being in turn attacked. There are many modifications of this general system practiced in the various regions of the State.

In laying out the underground workings of mines, a plan of the proposed system of working is usually made in advance by a competent practical mining engineer. The conditions must be carefully investigated as to drainage, the nature of the roof and floor, the texture of the coal, and the weight of the overlying strata. It is not always practical to follow the letter of the plan laid down, owing to the irregularities of the floor, and to the presence of horsebacks, but the spirit of the plan may be followed to the end.

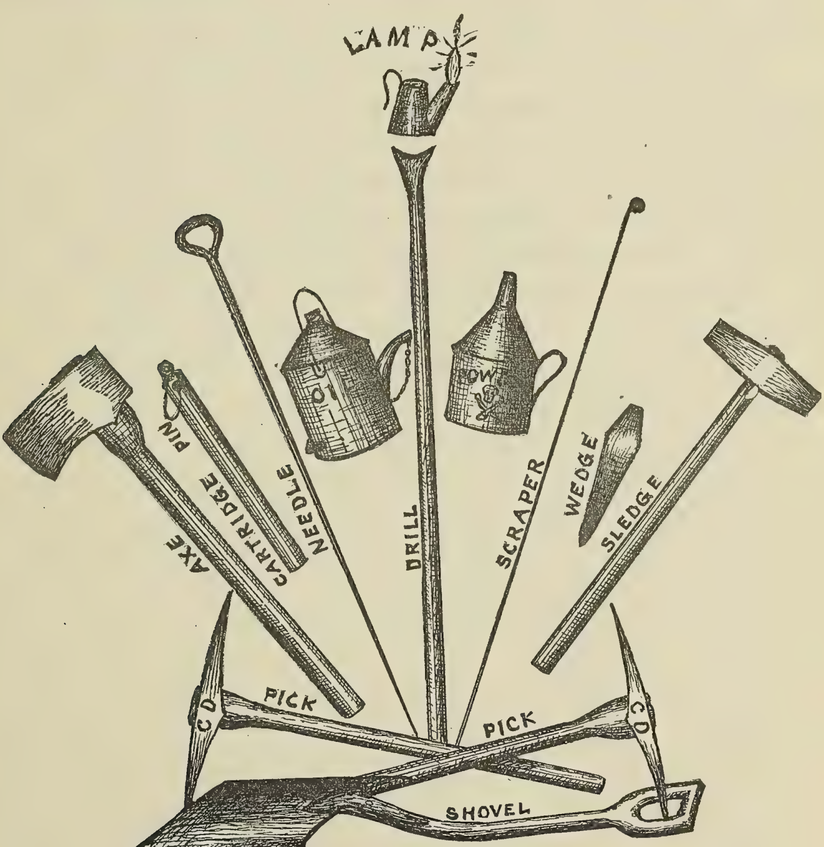
The double entry system obtains in all well-regulated mines; it consists in carrying forward two galleries in parallel lines on the face of the coal; a pillar of coal, 3 to 6 yards in thickness, being left between the entries, which is cut through every 30 to 40 yards for air. As a new air-hole is made at the face of the heading, the outer one is closed up, and made air-tight by a wooden brattice, or otherwise, so as to force the air forward to the working face. Butt entries are opened to right and left of the main galleries; they are also made double, and are in all respects like the main galleries. Entries are made much narrower than rooms; they are generally driven 8 or 9 feet wide, for the purpose of having the roof firm and safe. The rooms from which the great bulk of the coal is got, are opened in the butt entries. Rooms are started at the same width at which the entries are worked, but they are rapidly opened out to full width, 7 to 9 yards; they are worked both north and south, in lines parallel with the main galleries of the mine. Butt entries are 160 to 200 yards apart.

The pillars or ribs left between rooms are of varying thickness, according to the nature and weight of the overlying strata; under a firm roof and a light cover, ribs 2 to 3 yards in thickness suffice; they are made thicker in proportion to the weight of the overlying rocks. Thin ribs are cut through every few yards, but when they are 4 to 6 yards in thickness, break-throughs are less frequently made. These break-throughs, like those made between the entries, are cut for the purpose of keeping a fresh stream of air as near the face of the workings as may be practicable.

The pillars of the mine are generally allowed to remain until all the rooms are worked out; they are then attacked in the interior of the

mine, and cut away as clean as practicable, but a great part is necessarily lost by the falls which follow their extraction. Pillar-work is the most dangerous part of mining. In some mines the pillars are attacked as soon as the rooms are finished; under such circumstances it is necessary to leave strong supports along the galleries, to prevent the crushes and falls of the overlying rocks from overrunning the mine.

The manner of digging the coal is artful and curious. The tools of the miner consist of a sledge, 8 to 10 pounds in weight; several steel wedges, 6 to 8 inches long; 3 to 6 picks, from $2\frac{1}{2}$ to 3 pounds in weight, with handles 28 to 32 inches in length; a set of drilling tools, to-wit: a drill, a scraper, a needle, and a tamping bar; frequently the drill and tamping bar are made of one piece, one end being used for a drill and the other for a tamper.



SET OF MINERS TOOLS.

Two miners work together in rooms and entries; they keep each other company, assist in setting props; one watches while the other works in dangerous situations, and if one is caught, the other can raise the alarm and call in adjoining comrades to the rescue.

The first and the most laborious part of the work of coal digging consists in undermining, or bearing in, or holing the rooms. This is generally performed in the bottom of the coal seam with the pick. An undermining is made of varying depth, sometimes 3 to 4 feet, frequently 5 or 6 feet; the miner stands upon his feet, and strikes with all his strength, until a few inches in depth are bored in; he then sits down on the floor of the mine, his legs stretched wide apart in front of his body, and cuts in 6 inches to a foot deeper; finally he stretches his body along the floor, his shoulder and arm to the elbow resting upon his thigh, and in this constrained position finishes up the undermining. It will take two active miners 4 or 5 hours to undermine a room 8 yards wide and 4 to 5 feet in depth. Forty to fifty blows of the pick are delivered per minute, and considerable skill is exercised in holing. Miners raised to the work from boyhood are both speedier and cleaner workmen than those who assume the calling after manhood. There is a good deal of difference also in the nature of the undermining, some beds cutting easy, others hard. A room is not usually undercut across its whole breadth in preparing a blast, though it is better to so undercut it.

Having finished the undermining, the next thing in order is boring a hole for the blast. Some skill is also required in performing this work, so as to give the powder the best possible advantage. In some mines more reliance is placed upon the drill than upon the pick, the coal being largely blasted out of the solid. In doing so the miner shatters the coal, but this gives him little concern so long as it adds ease to his body. Coal is not mined now with the care and skill of 10 and 12 years ago. The amount of powder required for a shot varies from 1 to 8 pounds, the former amount sufficing when the coal is properly undermined—the latter amount being required in blasting out of the solid. As a general rule, a pound of powder is burned for every 3 tons of coal mined. In the Massillon region, where the main weapon of the miner is the drill, a pound of powder is burned for every single ton mined. In some mines powder is not required, the coal being knocked down, after it is undermined, with wedge and sledge.

The entries of mines are driven so narrow that prop-wood is not

required to maintain the roof in place, but all rooms need propping. Sometimes 4 or 5 rows of props, planted 3 to 4 feet apart, are required to make the roof safe. The props are sunk in the floor a few inches, and are surmounted with a flat-cap, about 2 inches thick, and 10 inches wide, and 18 inches to 2 feet in length. Some mines require only one or two rows of props. The roof is not uniform throughout the mine; in one part it may be hard and strong, in other parts, tender and treacherous.

The railroad track of mines is about 3 feet in width; along the main entries the rails are made of T-iron, 12 to 16 pounds to the yard; in the rooms scantling is generally used, the size of the rail being governed by the weight of the loaded mine cars. Providing a good T-iron track all over a mine, entry and room alike, is true economy on the part of mine owners, although the first cost may be greater.

A good track and abundant ventilation are found wherever good mining engineering practice prevails. Mules cannot haul coal over bad roads; miners cannot work in bad air. Nature will rebel; the mule may be lashed by the driver, but he will retaliate with his heels; the miner may be cursed by the boss, but he will retaliate with a strike.

Mines in which the coal is 6 feet high use horses for hauling; below this height, mules are used.

Beds lower than 4 feet require to have the roof ripped, to admit the hauling with mules. In low veins, a frequent practice is to employ pushers to push the mine cars from the working faces to the hauling roads or entries. This is the practice in the Steubenville district of Jefferson county, and the Coalton district of Jackson county. It costs less to employ men as pushers than to rip the roof to admit mules.

Along the main galleries the roof is ripped from end to end, and mules do the hauling to the main shaft or mouth of the drift, as the case may be.

In the thicker beds of coal the mine cars hold 1 to $1\frac{1}{2}$ tons; in the thinner veins, $\frac{1}{2}$ to 1 ton. Thick beds cost less than thin one for hauling coal, and other dead work. The cost of the dead work of mines ranges from 15 to 40 cents per ton; this includes entry-driving, cutting air-ways, cutting ditches, blasting roof and bottom, laying track, providing props and rail timber, and hauling, dumping, and loading coal.

Three grades of marketable coal are made at mines, "lump," "nut,"

and "pea," the latter, which is the finest or smallest variety, is not made at all mines. The space between the bars of the screen is 1 to $1\frac{1}{4}$ inches; occasionally wider or narrower bars are used, but they are exceptional cases. All coal which does not fall through the bars of the screen is called "lump." A second screen, with bars $\frac{1}{2}$ an inch apart, separates the "slack" from the "nut." Pea coal is made by screening the nut coal. The slack is raised from the ground by a self-loading elevator, and thrown into a revolving circular screen, which thoroughly sifts out the fine coal which falls back to the ground, and is hauled away as refuse matter. At some mines the nut coal is washed and purified before being loaded for shipment.

The proportion of lump to nut and slack varies considerably in mines, partly owing to the nature of the coal, and partly to the skill with which the coal is mined. Tender seams naturally make more nut and slack than hard coal. In the Coalton or Wellston district, where the seam is unusually tender, two-fifths of the whole pass through a $1\frac{1}{4}$-inch screen, while in the Mahoning Valley, in the Brier Hill district, where the coal is hard and firm, only one-sixth of it falls through the screen. In mines in which powder is injudiciously used the coal is wantonly broken up into nut and slack. Unskilled miners make more fine coal than experienced workmen.

Work commences in the mines at 7 o'clock A.M., an hour is given to dinner at noon, and work ceases at 5 P.M.—nine working hours being a day's work. The diggers work by the ton, and are in a measure their own bosses. All the workmen are expected to be down the shaft or slope before the mules commence hauling. In mines in which heavy charges of powder are used in blasting out the coal, the workmen are forbidden from firing until 4 P.M.; in 5 minutes after the signal is given 40 or 50 discharges are heard, and such is the force of these blasts that the earth shakes above. Vast volumes of smoke load the air of mines after these subterranean discharges.

In some mines firing is allowed twice a day, at noon and quitting times, and in the Steubenville district, where small discharges of powder suffice, and the ventilating currents are unusually strong, the workmen blast at all hours of the day, and suffer no inconvenience in consequence.

All shaft mines are provided with cages or elevators, upon which the loaded and empty cars are raised and lowered through the shaft.

Cages are provided with safety-catches or locks designed to hold the cage in the guides, and prevent it from falling in case the rope should break. On the top of the cage there is a cover of oak boards or sheet-iron to protect the workmen from falling stones, and in front of the shaft, at the landing on top, self-acting gates are placed, which are lifted out of the way by the ascending cage, and drop back as the cage is lowered, and guard the entrance of the shaft. Not more than ten persons at once are allowed by law to ascend or descend a shaft mine. Signaling arrangements are provided at all shafts, consisting of a bell or hammer, for the information of the hoisting engineer. When a loaded car is pushed on the cage at the bottom, the cager below raps once, signifying that coal is coming up; two raps are for the return of the cage, and three raps that men are about to be hoisted, when the engineer exercises more than ordinary care. The system of signaling is not uniform at mines, though it should be. The best signal arrangements in the State are in use at the Garfield shaft in Trumbull county. There is a bell on top and one at the bottom. When men are about to be hoisted the cager below raps three times, the engineer answers by one rap, and until this is done no person is allowed to step on the cage. After the miners, not more than ten in number, are safely on the cage, the cager knocks again, giving one rap; the engineer answers that he is about to start by one rap, and the men are carefully raised to day.

This mine has also a good speaking tube, so that conversations can be held between the engineer and persons in the mine. All mines in which the human voice cannot be distinctly understood from the top to the bottom, should be provided with speaking tubes.

Labor-saving Machinery in Mines.

Improvements are constantly being made in mining, and hauling, and dumping coal, some of the more prominent of which deserves to be noticed. The mines of the Shawnee Valley Coal and Iron Company have been improved during the past year by the erection of a substantial hauling engine and wire rope. The mine is a drift, opened on the face of coal, and dips 30 feet in 3,000 feet. The engine cylinder is 12 inches diameter, and 20-inch stroke, built at Norwalk Iron Works, Connecticut.

The rope is $\frac{3}{4}$-inch Norway iron wire, 6,000 feet long. The coal is hauled about 3,000 feet, 24 cars per trip. The rope passes three

butt entries, from which coal is hauled. These entries are double in starting, but the two come together to facilitate hitching. The mine cars hold 30 hundred screened coal, and three trips per hour are averaged, equal to 108 tons of lump coal. This does away with 12 horses, which, with drivers, would cost $30 a day. The cost now is $7.50 per day only, three men being employed with the machinery. The mine it getting out 700 tons of lump coal a day, which will be increased to 1,000 tons a day, as soon as sufficient mine cars are made. The company commenced putting in this machinery January last, when the trade fell off, and brought out the first coal in three weeks. There was some difficulty and delay at first in getting the machinery to work well. There are three curves on the road, the first being 37 degrees. The cars come around this curve without any trouble now. The arrangement is admirable.

The new and extensive mines of the Murray City Coal Company, in the Hocking Valley, have been fitted up with machinery for raising coal, of unsurpassed excellence. The opening of the mine is a slope, which dips one foot in five, and the machinery for hauling out the coal consists of an endless wire rope, operated by a stationary engine placed at the top of the slope. The hauling road is double, and loaded cars come up on one track as the empty cars descend the other. The cars attach themselves to the wire rope by means of an automatic clamp; the rope never stops, and the cars attach themselves to it as soon as they are brought to the bottom of the slope. On being delivered at the knuckle they detach themselves, pass forward into the dump-house, and tip of their own accord over a Mitchell dump, one of the best arrangements for dumping coal ever contrived. This dump is so constructed that the loaded car tips over automatically, its speed being regulated by a brake, the handle of which is within easy reach of the dumpman. After the car is emptied, it falls back in place, and the advancing loaded car strikes a spring, which throws the tip irons outward. The loaded car then strikes the empty one standing on the tipple, and pushes it forward out of the way, the tip iron then springs back in place, and holds the loaded car, which is dumped in turn. The empty car moves forward on a gently declining grade to a Y-switch. The road immediately beyond this switch is graded upward, and the empty car reverses its motion, runs back into the switch, is caught by the automatic clamp of the wire rope, and lowered down the slope into the mine. Only one

man is required to do the dumping, and he could easily manage a thousand mine cars a day.

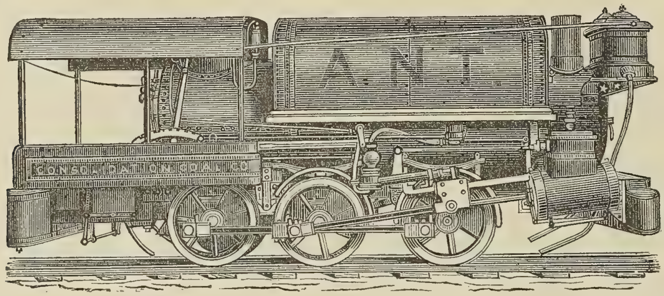
The mines of the State Line Coal Company, situated at East Palestine, Columbiana county, have very superior arrangements for hauling coal, and washing the slack or screenings. A stationary engine is erected outside, which operates an endless wire rope, which extends underground $1\frac{1}{8}$ miles. A loaded train of cars, 50 to 60 in number, is hauled outside at once, and delivered in the shoots, and the empty train of cars is hauled back into the mines over the same track. Conversations are held between the engineer in charge of the engine outside and the hitcher-on in the interior of the mine, by means of a telephone, and all the arrangements are admirable.

The washing machinery for separating the slate and other impurities from the nut and slack coal redeems fully 14 per cent. of the output of the mine, which was formerly unfit for any purpose, and was thrown aside as waste. This coal is washed and purified by a stream of water, which is poured upon it, and which carries it through a long narrow trough; the slate and other impurities of the coal being the heavier bodies, fall by the way, and lodge in the bottom of the trough. The engine which runs the wire rope upon which the mine cars are hauled to and fro, also operates the slack-washer. The State Line mine is the largest in Ohio in point of production, the average annual coal output exceeding 100,000 tons. The mine is managed by Hugh Laughlin, a practical mining engineer of consummate skill and judgment.

At the mines of the Prospect Hill Coal Company, operated by Mr. James Suthern, situated also at East Palestine, the coal is brought out of the mine by means of an endless wire rope. A small single shaft engine is placed at the mouth of the mine, which is not reversible, but the drums of the shaft reverse, and the full trips are brought out, and the empty ones returned as fast as the coal can be gathered on the entry.

Underground hauling machinery is also used at some of the mines at Steubenville, and at the new slope of the Ohio Southern Coal and Iron Company, in Jackson county, costly and elaborate hauling machinery has been fitted up. The coal is raised up the slope by means of an endless steel wire rope, $1\frac{1}{8}$ inches in diameter, which passes around eleven different sheaves at the top of the mine. Four of the sheaves are ten feet in diameter, and seven of them four feet in diameter.

Small locomotives have of late years been introduced in a number of coal mines in the State to do the work of hauling underground.



MINE LOCOMOTIVE.

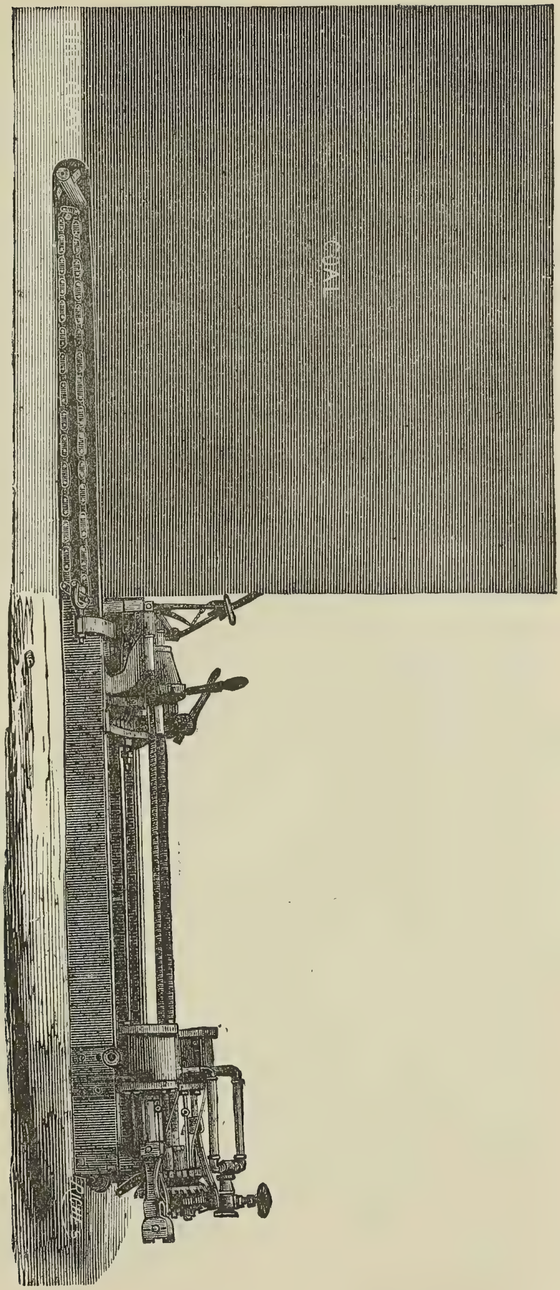
The first trials of mine locomotives were made in Pennsylvania, in the anthracite coal fields, but they are now found in all the coal mining states. As compared with stationary machinery and wire ropes, they hold their own, but they are objected to by many on account of the smoke and gas generated from the coal. In the hands of an intelligent mining engineer, who is master of the art of mine ventilation, they can be used with perfect safety, but taken where uneducated and unskilled men control the mining department, they are dangerous forces, and their introduction has frequently led to fatal consequences.

Wherever mine locomotives are used, it is necessary for the health and safety of the miners to ventilate the workings with air, which is not allowed to come in contact with the current amidst which the locomotive moves, and a column of wind of 25,000 cubic feet per minute, and moving at the rate of 5 miles per hour is required to rid the mine of smoke and keep the galleries in a fit state for miners to occupy.

Coal Cutting Machinery.

Two coal cutting machines are in use in mines in Ohio—the Lechner machine and the Harrison machine. The Lechner was introduced in the mines of the Straitsville Central Mining Co., in Perry county, in 1876, and since that time it has been extended to several other districts in Ohio and to a number of the mining districts in Pennsylvania, West Virginia, Kentucky, Alabama, Illinois, and Colerado, and last year found its way to some of the mines in Great Britain.

This machine is only 20 inches in height, and can be used in seams of coal three feet thick and upward. It is wrought by means of com-



COAL-CUTTING MACHINE.

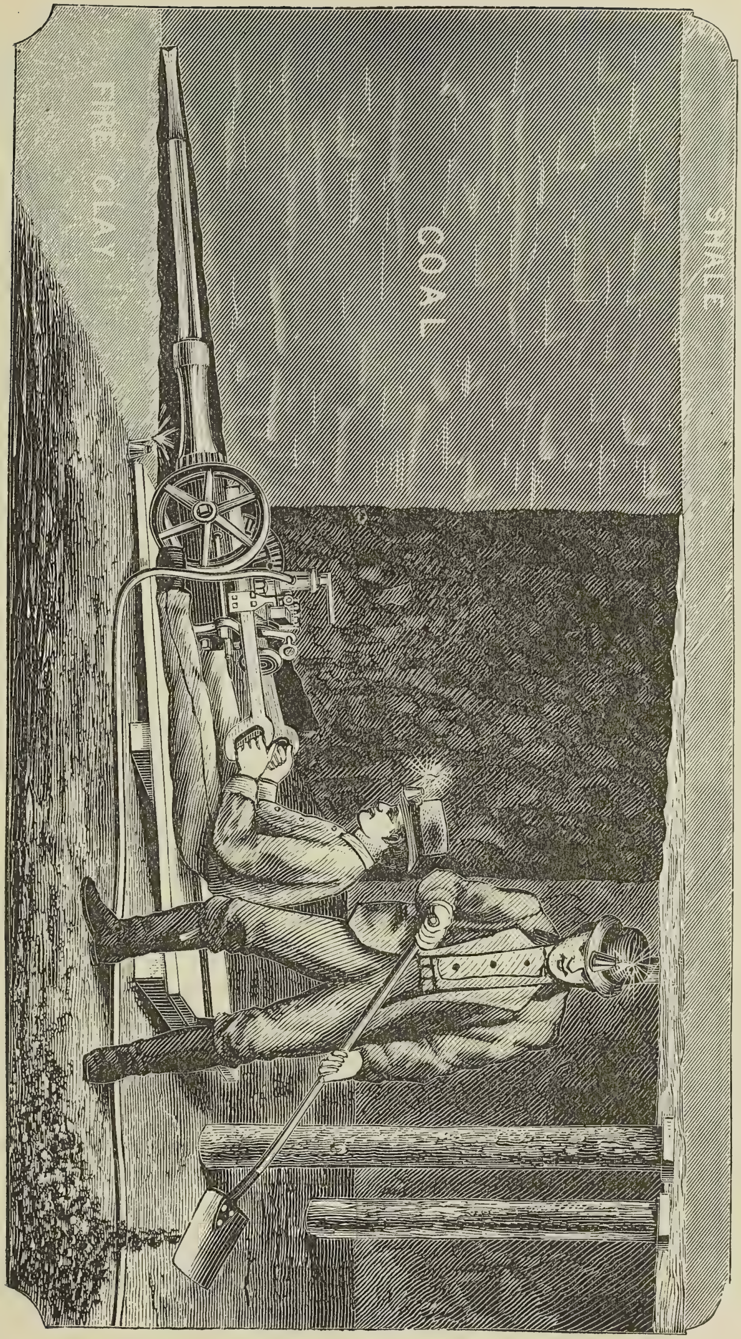
pressed air; the coal cutter consists of a horizontal bar three feet in length, to which a number of sharp steel knives are attached. The bar revolves and the knives grind the coal to dust, cutting a groove 4

inches in height and 5 feet deep at each attack. The machine is shifted over three feet and a second attack made, and so on until the whole room has become undermined to a depth of five feet. An undercutting of 100 lineal feet is regarded as a fair day's work for one machine. In some mines the undercutting is made in the fire-clay floor, and all the coal is saved; in other mines it cannot be used in the floor.

The Harrison coal-cutter was first applied in the mines of Illinois, by the Diamond Coal and Mining Co., and in 1880, the Chicago, Wilmington and Vermillion Coal Co. of the same State, one of the wealthiest mining corporations in the west, applied 10 of these coal-cutters, and they soon found their way to Ohio mines. The coal-cutter consists of a pick 8 pounds weight and 10 inches long, operated by a piston. The pick, which is made of solid steel, has two points, and undercuts the coal in much the same way as the miner does. This machine is much lighter, and is more easily moved about than the Lechner, but it effects no saving of coal over the ordinary method of hand-mining. Both machines have their advocates, and either of them is an improvement over manual labor. A few months ago the Harrison machine was introduced into the iron ore mines of the Hanging Rock region, and will prove a more successful digger of iron ore than of coal.

The introduction of coal-cutting machinery was looked upon with a jealous eye by the miners, and yet it will come not as their enemy, but as their best friend. It will not drive out the miner, but will lighten his occupation, and give him brain labor. It will take away the laborious work of undercutting, at once the most constrained and exhausting work to which the human frame can be put. The floor of mines is always damp, often wet, and the miner is required to lie down on his side, and burrow away underneath the coal for 4 or 5 feet. Lumbago and rheumatism attack him in consequence.

A large number of coal cutting machines have been introduced from time to time into the mines of Great Britain. Only a few of them have been found in practice to hold their own. Coal, the foundation of the power which sets the machinery of the world in motion, has been found one of the most difficult industries to which can be applied labor-saving machinery.



HARRISON COAL-CUTTING MACHINE.

Examples of Good Mining Practice.

The manner of mining in some of the older and more important regions of the State, where good practice generally prevails, will now be briefly described.

The system of mining in the Mahoning Valley, owing to the conditions under which the coal was deposited, is peculiar and curious. The coal, which is the lower bed of the State series, is subject to sudden changes of level, and is found disposed in long, narrow, and serpentine basins or troughs. Generally these basins are separated from each other by large areas of barren ground, in which the coal is geologically due, but was never deposited; occasionally two or more of the basins run along side of each other in nearly parallel lines, the coal extending from one basin to another in the form of an anticlinal arch, without breaking its continuity, though becoming very thin on the high lands of the old coal plain. The low ground in the coal bed is called a swamp by the miners. Owing to the structure of these swamps, the workings cannot be laid out with any degree of symmetry, and peculiar mining skill is required to guide and direct the subterranean excavations. The line of direction of the swamps is very sinuous, resembling the bed of a rivulet, and the main galleries of the mines have to be opened in these swamps, following their lines of direction through all their sinuosities, in order to drain the workings of water.

The mines are all shaft openings, ranging in depth from 50 to 250 feet; the stratum overlying the coal is a hard and compact gray shale; the floor is a firm, hard, sandy fire-clay, and the coal seam itself is a hard, firm, compact, block coal. When to these conditions are added the fact that the basins are generally quite narrow, seldom exceeding a few hundred yards in width, small pillars suffice for the support of the overlying rocks. The main entries of the mine, which are driven from 8 to 9 feet in width, follow the swamp, as I have said, wherever it may lead, the line of direction of the swamp being usually southwest. At intervals of 160 yards, branch entries are driven on the butts of the coal, and the rooms, which are usually 10 to 12 yards wide, are worked at right angles from the butt entries; pillars, two to three yards in thickness, which are cut through every few yards for air, being left between rooms to support the roof.

All the entries of the mines, face and butt alike, are driven in the swamp when it is practical to do so; as the seam of coal is seldom high

enough to admit of the hauling mules, the roof is ripped for a foot or 18 inches. The coal is not everywhere got by shafting; a favorite method of sinking is by opening slopes on a dip of 30 degrees. Slopes which do not exceed 100 yards in length, are as cheaply opened as perpendicular shafts, 100 feet in depth; the cost of sinking is greater in slopes, because of their greater length, but less costly machinery suffices for hoisting. Slopes are usually made 10 feet wide and 6 feet high, with a single track. A train of loaded cars, two or three in number, is raised; an empty train is then sent back, and in this manner 500 tons a day of 9 hours is a fair average at a well-regulated mine; in the larger mines 600 or 700 tons constitute the daily output. The best mines, however, are being rapidly exhausted, but further southwest, on the line of direction of the swamp basins, new discoveries are rewarding the research of the mining adventurer, and many years must elapse before the day of complete exhaustion occurs. Owing to the increasing depth of the coal below the surface, in following up the basins along their line of dip, the newer mines are mainly shaft openings—slopes, as already stated, seldom exceeding 100 yards in length.

The miners of this region are of mixed nationality, the Welsh being more numerous than others. In the mine of the Church Hill Coal Company, one of the largest in the valley, eight different European nationalities are represented underground, in the following order as to number: Welsh, French, Scotch, Italians, German, English, Irish, and Greeks. In a large and well-regulated mine in this region as many as 200 to 250 men and boys are employed underground. Where 200 men are engaged digging coal, the average output of the men will reach 600 tons per day. This will require an underground force of 15 mule drivers, 10 to 12 road men, 5 or 6 trapper boys, 1 furnace man, 1 cager, 2 or more pumpers or water bailers; while above ground 3 or 4 topmen, 2 dumpers, 1 trimmer, 1 weighmaster, 2 engineers, 1 hostler, and one general overseer or mining boss are required. It requires from 40 to 50 per cent. added to the cost of mining and loading to pay for the day-men, and other dead work of the mines, the cost of dead work being lessened or increased according to the varying circumstances and conditions of mines.

Four feet is the standard height of coal for which the miners are paid per ton for digging and loading. Above this thickness, no decrease in price is allowed, but for every 3 inches of decrease in thickness below

4 feet, the miner is paid 5 cents additional, until the coal seam recedes to 2 feet, no coal being mined, except in rare cases, below this thickness.

The cost of opening and equipping a mine in this coal region often exceeds $20,000, but if the coal proves of good quality, as is usually the case, the money is soon refunded. The mines had been very profitable—more profitable than those of any other region in Ohio, owing partly to the proximity of the coal field to Cleveland and Lake Erie, but largely to the superior quality of the coal, which is of unequalled excellence. The better paying mines have frequently cleared for their owners, after all expenses are paid, including interest on capital invested, and wear and tear of machinery, from 75 cents to $1.00 per ton. Not all enterprises pay this well, however, and some of them are losing concerns resulting from a variety of causes, as, for example, the inferior quality and limited quantity of the coal, or the too abundant flow of water, etc. The mine of the Leadville Coal Company, situated 3 miles west of Youngstown, is an instance of this latter kind.

The history of this mine is so remarkable, that a brief sketch of it may not be out of place. The work of sinking this shaft was one of the most difficult and costly undertakings ever encountered in the United States, mainly by reason of the flow of water. The time occupied in sinking, including several long stoppages, was about two years and six months. The shaft was first let by contract to a party of four miners, at twenty dollars a foot, the company (Messrs. Wicks and Wells) agreeing to furnish pumping machinery for the discharge of water. The sinkers only succeeded in getting down to the solid material, when, finding it was impossible to complete the work for the price, with everything in their favor, they threw up their contract. A second party undertook the work at thirty-five dollars a foot, but also gave it up after a trial of three weeks. A third party took it at fifty dollars a foot, which was a fair price for work of this character on good ground. This party, strongly impressed with the necessity of having the water under absolute control at all times, sunk a seven-inch drill-hole in one corner of the pit, down to the coal, into which they introduced the suction pump of a No. 6 Cameron steam-pump, suspending the pump in the shaft, and lowering it as the sinking progressed. This arrangement worked very well; but the rock was very difficult to blast; the sides of the shaft were hard to dress, and the undertaking was a loss from the

first day. The rock—a coarse-grained sandstone—was of very porous nature, into which it was impossible to introduce naked powder for blasting. It had no partings, and the work of sinking was slow and costly, but the contractors persevered, knowing that the sandstone, as revealed by the borings of the large drill-hole, would be softer and easier to blast, the deeper the pit went into it.

But every additional foot of depth increased the volume of water, till at the depth of sixty feet the pump was kept running at its full capacity. The contractors now applied to Messrs. Wicks and Wells for additional pumping power, which they felt very reluctant to provide. The sinkers wanted a duplicate pump, as the breaking of any part of the one in use would necessitate its withdrawal, and fill the shaft with water, entailing needless expense and loss of time. After much hesitation and delay they got a second-hand pump of the same number, but of a larger make, no part of which could be used on the other pump, and this third party were forced to give up the contract, having lost two thousand dollars in the shaft. Most of this loss, however, was in sinking the large drill-hole, reconstructing machinery, and in the purchase of tools and fixtures for handling the pumps, and in a forfeiture of sureties (ten dollars a foot) for the completion of the work.

Messrs. Wicks and Wells now concluded to sink the shaft by day-work, themselves personally superintending the operations, and hiring and paying the sinkers. A second pump was soon found necessary, and then a third one, pump after pump being added, until six steam pumps were in the shaft, capable of discharging 3,000 gallons of water per minute. Little or no progress could be made with so many pumps, the work of sinking was suspended, and a new shaft, 8 by 12 feet, was laid out alongside of the main shaft, and sunk down to the level or bottom of the main shaft. Some of the pumps were removed to the new pit, and progress was resumed below; at the depth of 110 feet, however, a large crevice in the rock was struck in sinking, from which the water rushed with such force as to throw the drill high up in the shaft, and all the pumps were overpowered. They were all withdrawn, and the shaft filled with water.

After some weeks of stoppage, all the pumps were again set to work, and the water pumped out down to the point where the pressure of the water and the power of the pumps were balanced. All the pumps were run to their fullest capacity for four weeks, discharging

three thousand gallons a minute, in the hope of emptying, or at least controlling the feeders of water, but no impression was made. It was deemed necessary to further progress to procure one powerful pump, equal to the combined force of the six in use. Accordingly, one with a steam cylinder twenty-six and one-half inches diameter, and a water cylinder of sixteen inches diameter, with fourteen-inch suction pipe and five-foot stroke, made expressly for the purpose, was brought into requisition. The water was now mastered, but the difficulty was to get a sump made below the crevice so as to get a chance to close it up. The bottom of the shaft was a vast array of suction pipes, and the water flowed in from the crevice in floods. The pumps suspended above the workmen filled the shaft. Every one who has handled pumps in sinking will conceive of the difficulty of keeping so many pumps and pipes, suspended as these were by iron rods, in working order, all having to be lowered as the sinking progressed. A cutting, two or three feet below the crevice, was finally accomplished, when the sinkers addressed themselves to cleaning out the crevice, so as to fill it up with wooden blocks to dam back the water. The blocks were well wedged in and caulked, and the water was finally shut off and controlled.

The work of getting below the crevice was a labor of unparalleled difficulty and danger. The workmen, suspended in buckets, and having scarcely room to turn around among the multitude of pumps, labored heroically, though drenched with water, which shot in great streams across the shaft. During the whole of the undertaking not a single accident occurred. The closing up of the crevice reduced the flow of water to five hundred gallons per minute, and no further difficulty was experienced until the coal was reached.

In sinking this shaft, six thirty-feet boilers, with 36-inch head, were used. The cost of the work, including the necessary supplies for sinking, was $71,837, and the whole depth of the shaft was but 187 feet.

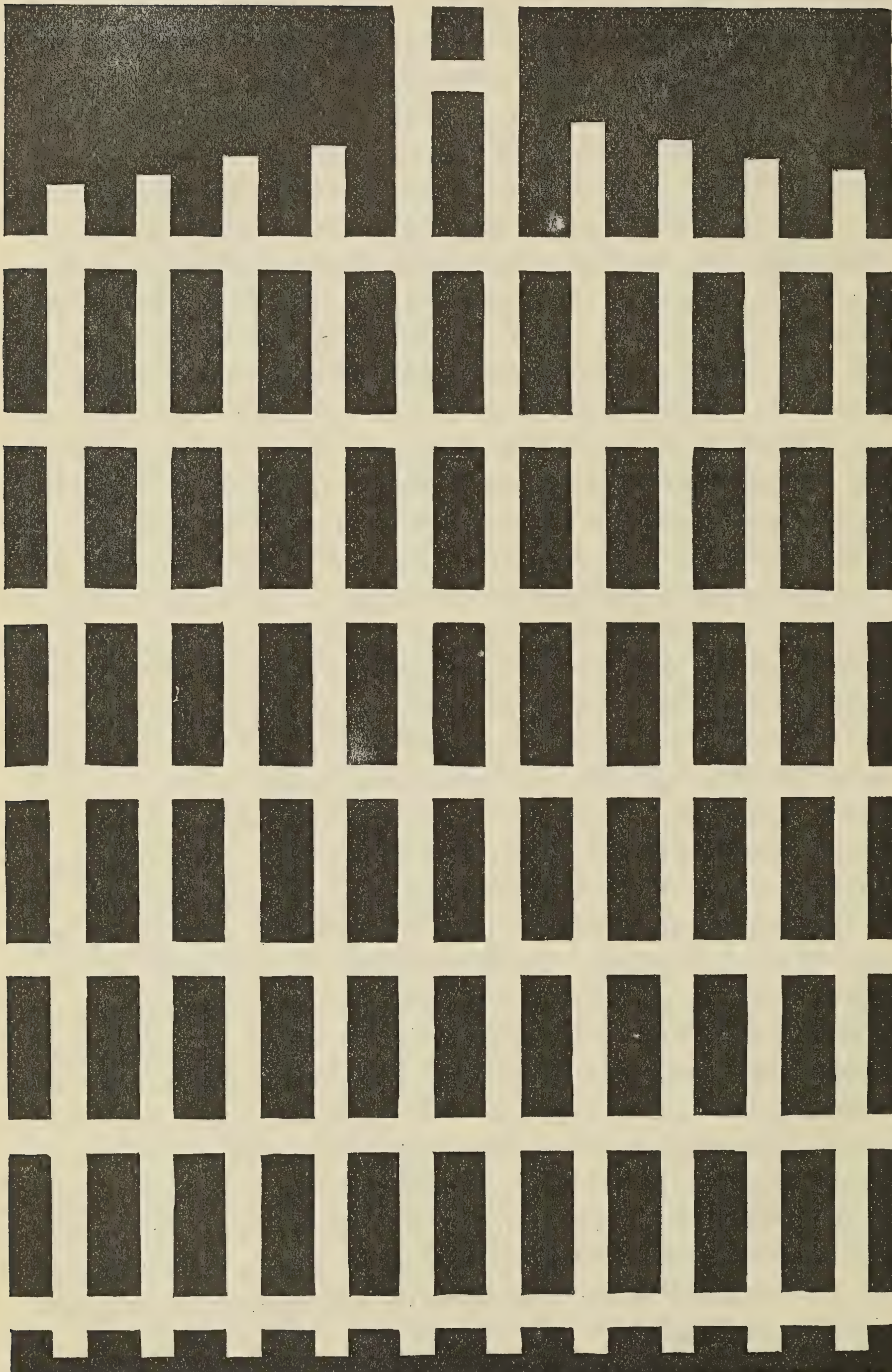
As the vast volume of water encountered in sinking was dammed back over the heads of the miners, its liberation by a fall of roof was only a question of time. Fifteen thousand square yards had not been excavated till the waters broke into the workings. All the miners escaped in safety, but the pumps were soon overpowered, and the shaft, with all its subterranean excavations, was again flooded.

The mine remained idle for 5 years. In the spring of 1880, the Leadville Coal Company was organized, which bought out the Messrs.

Wicks and Wells, the owners and projectors of the enterprise. A powerful hoisting engine of 400 horse power, built by E. P. Allis & Co., of Milwaukee, Wisconsin, and two bucket water-pumps, each of 27-inch bore, 6-feet stroke, and capable, while running 10 strokes to the minute, of discharging 3,500 gallons of water per minute, the pumps being designed by H. Hackney, Esq., Superintendent of the Mahoning Works, and built at the shops of the company in Youngstown, were applied for hoisting and pumping. Everything being in readiness, the pumps were started up in November, 1880; when the water was lowered to the depth of 136 feet in the shaft, one of the workmen accidentally dropped a steel wedge into one of the pumps, which stopped it, and it was found necessary to take this pump out to remove the wedge; in doing so the shaft again filled with water. In a few days the work of pumping was again resumed, and six weeks later the mine was pumped dry, and the miners, after an absence of five years, ventured down the shaft, and commenced mining operations. The mine having but one opening, and the excavations that had been made requiring a second opening, as provided in the mining law of the State, an escape shaft, or traveling way, was sunk into the mine, for the egress of the miners in case of accident, to the hoisting shaft. This traveling way was completed only two days, when the wooden structure covering and surrounding the hoisting shaft caught fire from a spark from the smoke-stack, and was burned to the ground. The miners found safe egress through the second outlet or traveling way; had there been but one opening, every soul underground at the time of the fire would have speedily and inevitably perished.

The fire, which occurred on the 21st of August, 1881, having destroyed all the buildings covering and surrounding the shaft, and disabled the pumping and hoisting machinery, all the subterranean excavation were again filled with water. The company at once commenced rebuilding the works and repairing the machinery, and on the 15th of October following, the pumps were again started up, and a month later the mine was once more pumped dry. There is an excitement in mining, unknown, perhaps, to any other industry, hence, all the misfortunes of this ill-fated mine have not in the least daunted the courage of the mine owners, or alarmed the fearless spirit of the miners, and work was resumed with the same degree of cheerfulness as in the beginning of the enterprise.

The mines in the Steubenville district, in Jefferson county, are



PLAN OF WORKING AT STEUBENVILLE.

worked on a plan nowhere else followed in Ohio, owing to the greater depth of the incumbent strata, as well as to the presence of firedamp ,which is given off in dangerous quantities. The plan is a model after that in use in the North of England, in which district the art of mining is better understood than in any other coal field in the world.

The rooms in the Steubenville shaft mines are made 18 feet wide, the cross-cuts or walls 12 feet wide, the pillars left being 24 feet in thickness, and 72 feet in length. The walls head off the rooms at right angles, and are driven straight forward in the butts of the coal, the rooms being driven on the face. The main entries, which follow the face of coal in lines parallel with the rooms are 10 feet wide and are double. The presence of fire-damp in the mine makes ventilation a paramount necessity, and so well is this art understood by the superintendents that not a single accident by explosion has occurred in the past 17 years. All of the mines rely on the furnace for the necessary currents of air, and every advantage is taken of the natural law to get the best results. The furnaces are made $5\frac{1}{2}$ feet wide, $3\frac{1}{2}$ feet high above the bars, and are 30 to 40 feet in length. The upcast of the shaft is roomy and dry, the air courses of the mine are wide and as straight as circumstances will permit, and fully three times as much air is set in motion with the same expense of attendence and fuel as in many other mines. The greater depth of shaft at Steubenville assists in creating the flow of air, for the practical power of the furnace is in proportion to the length of the up-cast, the power being as the ratio of the depth. The air current is kept well up toward the face of the workings; no sooner is a new holing made from the wall into the room face, than the outer wall is bratticed up and made air-tight. Should the current of air playing along the air courses be too strong for the comfort of the miners, an opening is left in the outer break-through for the escape of air until the miner has pushed his room ahead in the "fast" beyond the sweep of the circulating stream.

In order to guard against the possibility of danger none of the workmen in this district are allowed to descend any of the shafts in the morning, under any circumstances, until the mine has been thoroughly examined with a safety-lamp. At 4 o'clock in the morning, the mine boss, assisted by several trusted deputies, descend the mine, safety-lamp in hand. Every gallery and room is examined, each fire viewer traversing

the division of the mine allotted him by the mining boss. If gas is met in any working-place, the viewer takes off his coat and commences slashing among the fire-damp until it has become thoroughly diluted with the common air, and rendered harmless. In the rare cases in which the gas is too copious to be driven out in this manner, the place is marked by a danger signal placed at the mouth of the room, forbidding any person to enter until the gas has been driven out. This is done, either by taking forward brattice, or by driving a cross-wall to strike through at the face of the room.

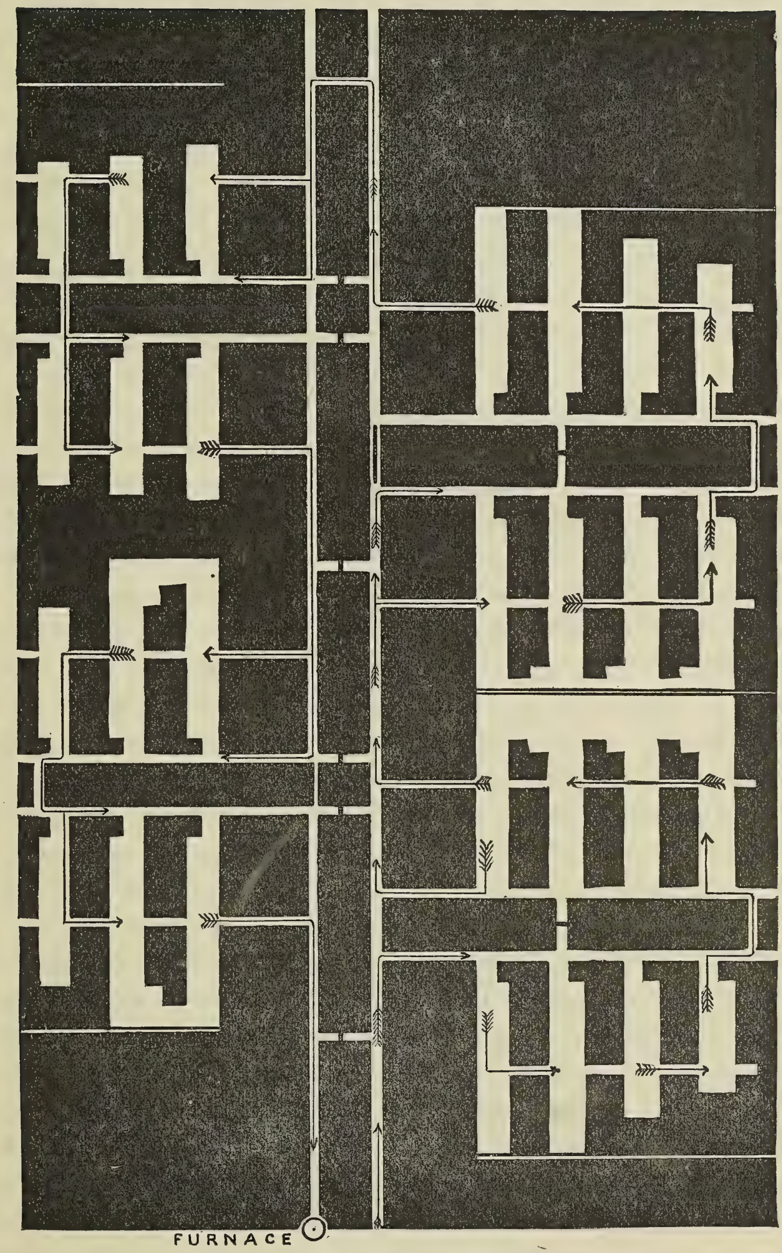
Having made the rounds of the mine the viewers meet at a pre-arranged station, and report to the boss. If everything is satisfactory, the examiners return to the bottom of the pit, and the signal is given for the miners to descend. The underground managers of this district are especially intelligent in dealing with fire-damp and the means of removing it.

The system of carrying forward the workings is simply admirable. Each working place advances as fast as another—all moving with mathematical exactitude. Every 3 months the miners ballot for places, and whoever is elected to any working-place, good or bad, is required to stay there until the next quarterly voting day arrives. By this arrangement no favoritism is shown, and everything works harmoniously.

The coal of the mines in this region is too thin to admit of hauling mules entering the rooms, and miners are employed to push the loaded cars from the miner to the mule road on the entry, and bring back the empty cars. They are called putters, after the English name. Three putters are employed at each station of 15 rooms. The shaft mines of Steubenville are among the deepest in the State, Rush Run shaft being 261 feet; Mingo shaft, 250 feet, and the Market Street shaft, 225 feet deep.

In the Pomeroy region, on the Ohio River, the system of working with double entries was first introduced in drift mines in this State. The mines were opened in 1833, and laid out on the single entry system, and reliance was placed on the natural forces for creating ventilation. Owing to the presence of black damp, the air was never good, and an improved method of working and ventilating the mines became a paramount necessity.

When the double entry system was introduced, the rooms were



PLAN OF WORKING AT POMEROY.

driven a distance of one hundred yards, and as soon as a room was finished the pillar was attacked, and brought back a distance of 50 yards, the remaining 50 yards being left unwrought in the mine. An un-

necessary quantity of pillar coal was sacrificed by this plan, and it was changed to the present method, which consists in working rooms forward 80 yards, and removing all the pillar coal after the rooms are finished or worked out.

As the mines are now worked, double parallel entries are driven in the face and butt slips of the coal. The butt entries are 160 feet between the blocks. Rooms are opened on the north and south, following the line of the face entries. The rooms are broken off the entry 7 feet wide, and are advanced 15 feet before being opened to their full width of 7 yards. The thickness of pillars between rooms is 6 yards, which are cut through when the rooms are worked forward 40 yards, for the purpose of getting better air.

The pillars of a range of workings are attacked as soon as the rooms are finished up. The pillars first cut away are those in the first range of rooms. As soon as a butt entry has been driven forward to its boundary, and all the working rooms finished up, the pillars of the four interior rooms are worked away. They are brought back in echelon with the purpose of throwing the weight of the superincumbent strata away from the miners. The roof of the excavated area is held up by a free use of prop-wood, and seldom falls in alarming masses until the air crossing 40 yards back has been reached. The slate forming the immediate cover of the coal now begins to fall, but the massive sandrock above remains firm. When the range of pillars has been cut away within 15 yards of the entry, the miners change front, and attack the entry stumps on the butts of the coal, and work them off.

The first range of pillars having thus been withdrawn, a new range adjoining those just removed is attacked, and worked away as in the first case, the slate falling down in the excavated space. When sufficient space has been made to allow the sandrock above to break, a week or ten days occurs from the time it begins to rend and crack before it finally gives way and falls. The rending of the rocks is terrific; loud cracking and rumbling goes on; sometimes the noise is loud and sharp, at other times it resembles the sound of distant thunder. Fragments of the pillar coal break and fly off, and finally the massive strata, several hundred feet in thickness, falls with tremendous noise and force. All this time the workmen continue robbing the pillars, secure from danger, under cover of the undisturbed portion of the mine.

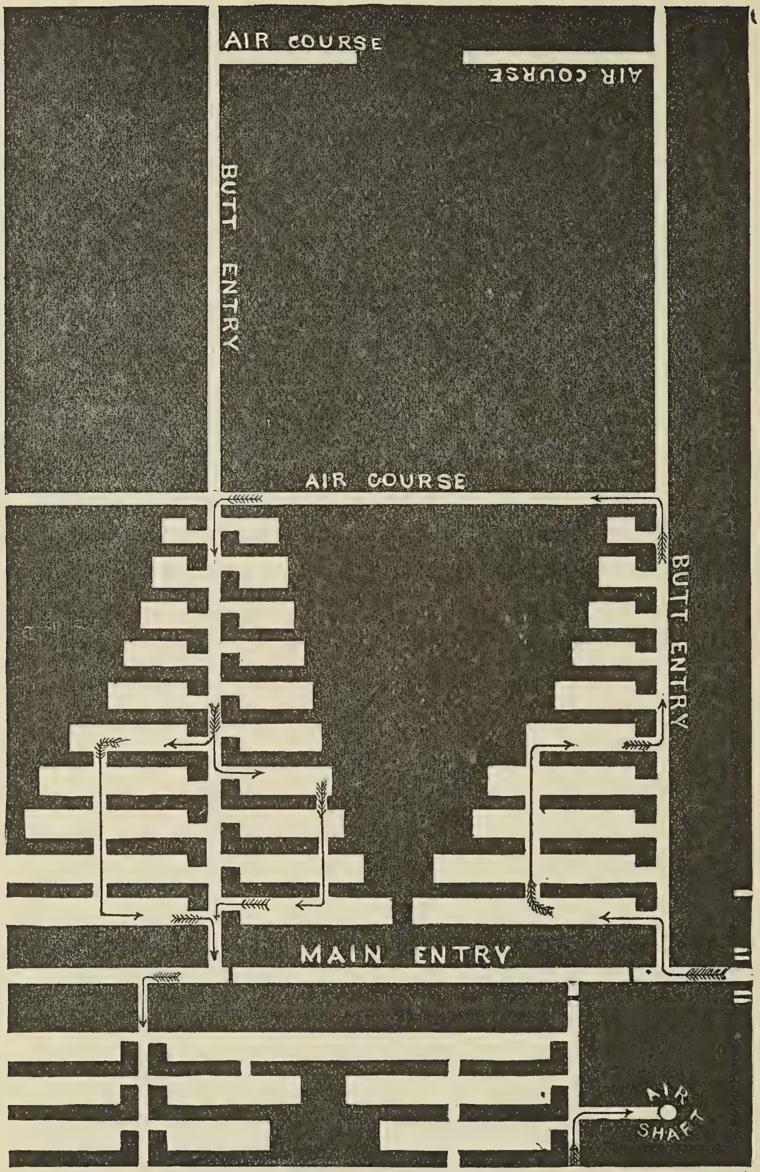
In some of the mines of the Hocking Valley, as well as in other

districts, the pillars are removed as the workings advance. As soon as a range of rooms is worked out, the pillars are attacked and worked back to the entry. The advantage of this system consists in getting the pillar coal while it is yet fresh; for coal deteriorates by drying out, when left in the pillars for a number of years. The expense of making new roadways is also avoided, but it requires skill, not always met in the management of mines in this State, to anticipate the results of drawing pillars, and quite frequently, the crush which follows their extraction, overruns the entries and destroys the whole economy of the mine. Experience, which is a good schoolmaster, is, however, throwing valuable light on this subject.

A plan of mining which still largely obtains in this State, consists in driving single entries, and starting rooms from off both sides of the butt entries. Doors are placed in the mouths of rooms on one side of the entry, and the air is carried forward along the entry, and returned inside of the doors. Less expense attends this plan, especially in low mines, in which the roof requires to be blasted along the hauling roads, than by driving double entries, but the ventilation is never as good, and any saving effected is usually swallowed up by strikes and stoppages, occasioned indirectly at least by bad air.

The above methods of mining, or some suitable modification of them, are practiced in every mining district of the State. Year after year improvements continue to be made, and many of our mines in their intricate subterranean departments show highly creditable engineering skill.

A simple plan of working mines still lingers in the Hocking Valley, known as the block system. It seems to have been borrowed from the Monongahela River region in the early days of mining, and is applied only by mining superintendents who have never seen better practice. It consists in dividing up the mine into a series of blocks or squares of 300 or 400 feet, all the entries and air-courses being single. The objection to the plan lies in the difficulty in getting forward air, and it is only practicable in mines which make no fire-damp and little of any other mineral gas. It has nothing to commend it, not even the plea of economy, and is disappearing before more advanced systems of working. In forming the blocks, the entrymen are required to work 500 to 600 feet ahead of the air-ways. To do this, rooms are usually not allowed to be opened until the air-courses are completed; sometimes, however,



PLAN OF WORKING IN HOCKING VALLEY.

for want of places, the mining boss will start up rooms before the airways are through, converting the working-places of the mine into a condition unfit for the healthy abode of man. Many a long strike has had its origin in just such places.

The Ventilation of Mines.

The more common gases which are met with in coal mines, are known among miners as fire-damp, after-damp or choke-damp, black damp, and white damp. Fire-damp is the light carbureted hydrogen gas of chemistry, and consists of one volume of the vapors of carbon and two volumes of hydrogen, condensed by affinity into one volume. One thousand cubic feet of atmospheric air at the temperature of 32°, and a pressure of 14.7 pounds, weighs 80.728 pounds, and one thousand cubic feet of fire-damp, under the same conditions, weighs 45.386 pounds; the weight of the fire-damp is, therefore, .562, as compared with common air. Being thus lighter than the atmosphere by nearly one-half, it occupies the roof and higher places in mines. In its pure and undiluted state fire-damp will neither support light nor life, but when mixed with twice its bulk of air it may be breathed, although with suffering. Fire-damp requires a mixture of five times its volume of air to constitute an explosive compound; with this proportion the explosion is very feeble. When a little more than nine times the volume of air is added to one volume of fire-damp, it forms a powerful explosive mixture. In this condition, the instant a naked light is brought into contact with the gas, it explodes with the rapidity and violence of gunpowder, and is liable to produce dreadful results. When more than fourteen times the volume of air is mixed with the fire-damp it again ceases to be explosive. Fire-damp is chemically composed of—

	By atoms.	By weight.	By volume.
Hydrogen	2	24.6	2
Carbon	1	75.4	1
	1	100.	1

After-damp is the product of an explosion of fire-damp, and contains, when the gas is exploded, 71 parts of pure nitrogen, 9.5 parts of carbonic acid gas, and 19 parts of steam. Immediately after explosion the steam condenses, leaving a largely increased proportion of carbonic acid, which is a most deadly gas. On the occasion of a disastrous explosion of fire-damp, more lives are generally lost from breathing the after-damp than from the rolling violence of the burning gas. The insidious after-damp spreads through the mine, and the miners are soon overpowered by the surcharged atmosphere. A painless stupor gradually overcomes them, and they fall asleep in death.

Black damp is the carbonic acid gas of chemistry; it is frequently called "stythe" by the English miners. Its effects on animal life are akin to those of the after-damp of an explosion. In its pure state it is a deadly poison, neither light nor life being capable of existing in it, and the miner's lamp, when placed in an undiluted stratum of it, becomes instantly extinguished as though it were plunged in water. When only 10 per cent. of black damp is diffused through the air of mines, a light cannot be maintained; where a light ceases to burn, it is never safe for a miner to trust himself for any length of time. Black damp contains two atoms of oxygen, and one atom of carbon; its specific gravity is 1.524, common air being 1; the oxygen, by weight, forming 72.73 per cent, and the carbon 27.27 per cent. of the gas. Being thus considerably heavier than air, it occupies the floors of mines when in a pure state, but, like other gases, it readily diffuses itself with atmospheric air.

The white damp of mines is the equivalent of carbonic oxide. This gas is much more deleterious to animal life than black damp, for air containing only 1 per cent. of white damp is unfit for human respiration, and if breathed for a few minutes will surely cause death. Unlike black damp, which ordinarily extinguishes the miner's lamp before prostrating his energies, white damp will support combustion amidst a deadly atmosphere. Miners have been frequently found dead in air charged with white damp, while their lamps continued to burn with great clearness. The effects of this gas upon animal life are similar to those of black damp, and to the after-damp of explosion: The miner falls asleep, and, if not speedily removed, he dies. White damp is composed of 1 atom of oxygen and 1 atom of carbon. By weight this gas contains 56.69 per cent. of oxygen and 43.31 per cent. of carbon; its specific gravity is 975.195, being little less than the atmospheric air. Sulphuretted hydrogen gas is also frequently found in coal mines. It is called white damp by some miners, like carbonic oxide; it is, however, readily distinguished from carbonic oxide by its peculiar smell, which resembles that of rotten eggs. Sulphuretted hydrogen consists of 1 atom of sulphur and 1 atom of hydrogen; by weight it contains 94.15 per cent. of sulphur and 5.85 per cent. of hydrogen. This gas is met in abandoned workings in which iron pyrites is undergoing decomposition. It is also generated by contact of hydrogen with sulphur in a comminuted form. Like carbonic oxide,

the miner's lamp will burn with clearness in a deadly mixture of this gas. When 3 per cent. of sulphureted hydrogen is found in the air of mines, human life cannot exist except with suffering. It produces fainting fits, giddiness and asphyxia.

These gases are generated in mines from a variety of causes. Fire-damp escapes from the fissures and minute pores of the coal and its associate strata. It is seldom met with in very alarming quantities in drift or level-free mines, or in shafts of moderate depth. The most fiery mines are those between 600 and 1200 feet in depth; below this zone fiery beds of coal are met, but it is the exception rather than the rule. Fire-damp exists in mines in a highly compressed state, being pent up in the interstices and fissures of the coal by the counterpoising pressure of the atmosphere. When the barometer falls, indicating a lightening of atmospheric pressure, the pent up gas escapes in great volumes. Many fatal mining explosions are due to this cause. The gas also frequently escapes in the form of blowers, which produce a hissing noice, and which, when ignited, burn like a long blow-pipe. The fire-damp of coal mines is one of the most fatal and dangerous elements ever encountered in human enterprise.

Black damp, like fire-damp, is liberated from the coal and its associate rocks; it is also generated by the burning of lights in the mine, by the exhalations of men and animals, by decaying woodwork, and by decomposing strata. The gases formed by blasting also aid in the formation of black damp. This gas is perhaps a more deadly, as it is a more subtle enemy of the miner than even fire-damp; the effects of fire-damp are instantaneous, while those of black damp are slow in operation, gradually but surely undermining the constitution, and killing its victims by inches.

White damp is formed largely from the products of exploded gunpowder; it is also generated freely in waste and abandoned parts of mines, particularly where breeding fires are liable to break out. Both sulphureted hydrogen and carbonic oxide are formed by breeding fires.

The presence of these gases in mines makes ventilation a paramount consideration in working coal or other minerals. Above ground vitiated air immediately flies upward into space, but the air of mines has to circulate from one working-place to another, frequently traveling from 10 to 12 miles, and supplying 300 men and many horses before it reaches the upcast shaft, and is delivered to day. As it moves along the

labyrinthian passages of the mine, it becomes more and more vitiated and unfit for breathing from the loss of oxygen, which is replaced by the noxious and poisonous gases met on the way. When we consider the numerous complaints which reach the public ear, over the condition of badly ventilated public buildings and workshops, and remember the numerous treatises which have been written on the best methods of improving the ventilation of such buildings, we are forcibly reminded of those dark subterranean workshops, amidst which the causes which tend to vitiate the atmosphere are multiplied a hundred fold, and where not even a ray of sunlight can ever come.

In laying out the workings of mines, two general systems are adopted, with the view as well to provide the means for circulating currents of air through the workings, as for mining away the coal bed, namely: the long-wall system and the pillar and room system. By the former method all the coal is withdrawn as the works advance progressively forward, the overlying strata being allowed to fall down and close in behind the miners, who maintain traveling ways by cutting up the floor or blasting down the roof. In the latter system columns of coal are left in the mine as the workings advance, for the support of the superincumbent strata, these columns being attacked afterwards; sometimes in a series of rooms as the workings advance, but more generally after all the rooms have been finished up to the boundary line of the mining plant. Long-wall mining, although it can be employed to more advantage in many seams of coal than pillar and room practice, has not yet obtained a foothold in Ohio mines, all our coal being won by the pillar and room system.

Pillar and room working, as its name indicates, consists in forming pillars and rooms, alternately; the proportion of coal mined away to that left standing being governed by circumstances and conditions. Rooms are made wide and pillars narrow when the roof is hard and firm, and the thickness of the overlying strata is not great; when the roof is tender and the superincumbent strata heavy, narrow rooms and strong pillars are required.

In opening a mine on the pillar and room system, gang-ways, entries, headings or galleries, as they are variously called, are first run forward on the face and end-slips of the coal bed. These entries, which in all well-regulated mines are made double, constitute the main avenues of the mine; they are usually driven much narrower than the rooms or

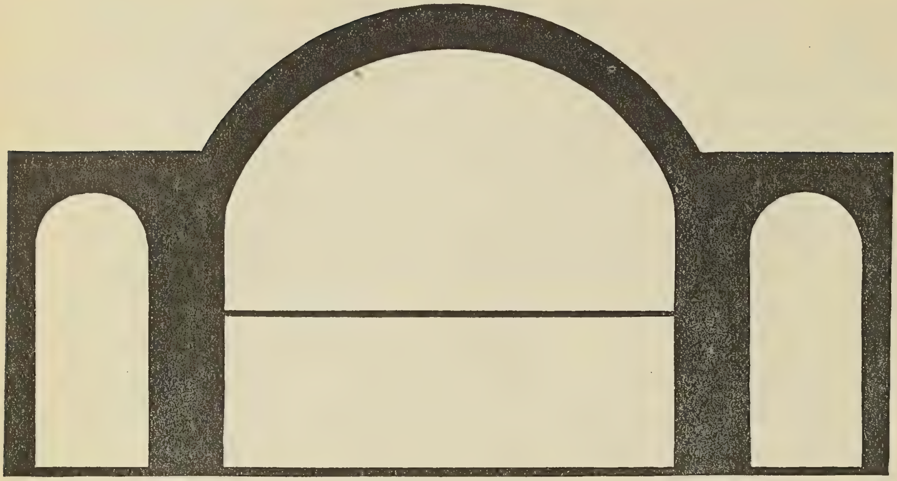
chambers, so as to make them extra safe, as well as to add strength to the pillars. The rooms are invariably started off the butt entries of the mine. In both entries and rooms, break-throughs require to be made from one working-place to another at stated intervals for the passage of the ventilating currents of air.

In all of the mines in this State in which improved mining systems are understood, no working-place is driven forward more than 40 yards ahead of the circulating currents until a break-through is cut in the pillar from one working-place to another. All break-throughs, except those last made near the working faces of the mine, are built up and rendered air-tight by brattice, trap-doors, or otherwise, in order to force the air-currents forward where the people are employed, for the tendency of the current is to follow the easiest route to the upcast.

In mines in which no fire-damp is given off, fully 100 cubic feet of air per minute should be circulated per man; in mines which make fire-damp a much greater quantity is required, particularly if the fire-damp is emitted copiously. But this current must be made to sweep through the interior of the mine, where the men are employed, or it will do little or no good. There may be ten times the amount of air required for the sanitary condition of a mine entering by the intake, and discharged by the upcast, and yet the working-places in the interior be in a very defective condition. Under every system of ventilation there is a loss of air by leakage.

When two separate openings of different depths are made into a mine, a current of air is set in motion by the natural pressure of the atmosphere. In winter the lower opening will be the downcast, and in summer it will be the upcast, because during winter the atmosphere outside is denser, and consequently heavier than the air of the mine, while in summer the reverse is the case. During those seasons of the year in which the mine atmosphere and the air outside approximate each other in density, there will be no motion, or it will be so slight as to be of little service.

As underground excavations become more extensive, the natural forces, even during seasons most favorable to their operation, become wholly inadequate as a ventilating power, owing to the resistance which the top, bottom, and sides of the air-way offer to the moving current of air, and artificial ventilation has to be applied to produce the circulation required to sweep away the gases and render them harmless. Furnaces



FURNACE

and fans are the powers applied to produce artificial ventilation. Frequently, exhaust steam from the steam-pump at the bottom of the upcast or pumping shaft is applied; but while this is a valuable auxiliary, it is too weak a ventilating force in a large and extensive mine to be used alone.

The furnace has long been the favorite method of producing ventilation among practical men, but of late years exhaust fans of the Guibal, Schiele, Waddle, and other patterns have been introduced, and have worked so successfully as to supplant the furnace nearly altogether over large and important mining districts in England and the other continental States of Europe. The furnace in its first cost is cheaper than the fan, and in deep mines is capable of doing equally effective work, while in shallow mines the fan is both cheaper and more effective as a ventilating power. The furnace is likely, however, to continue a ventilator as long as coal mining is followed.

The proper construction of a ventilating furnace is a debatable question among mining engineers. A thin, wide fire, and low arch more effectually heat the passing current of air, than a furnace having a high arch. The arch, in my judgment, should never be higher than $3\frac{1}{2}$ feet above the bars, and the wider the furnace is, the better, and the whole width should be kept constantly and uniformly heated. As furnaces are ordinarily built they do not admit the whole amount of air which they are capable of moving; hence, it is found to add to their ventilating power to provide side chambers. The object of these chambers is to

admit the passage of columns of cool air between the furnace and pillars of coal for the purpose of preventing the pillars taking fire, but the chambers are found in practice to add to the amount of current.

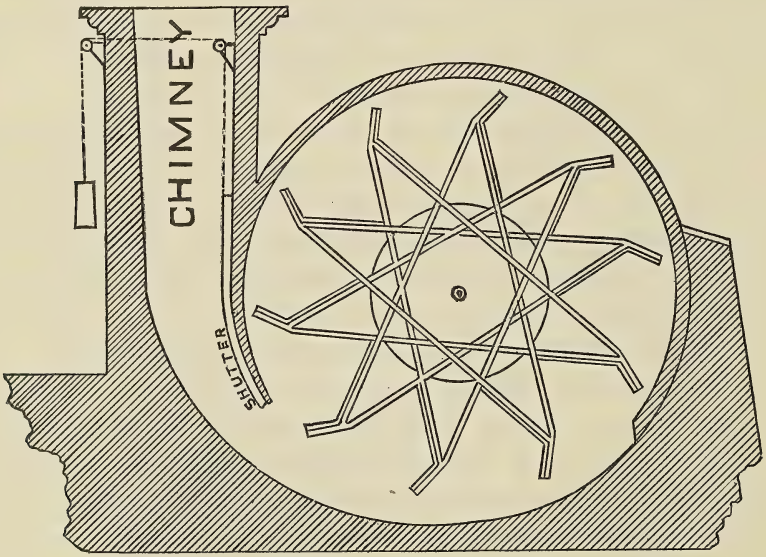
Where the air-ways of a mine are of, say 30 feet of sectional area, a furnace 7 feet wide and 3½ feet high above the bars will, I think, approach systematic perfection. The furnace has a limit to its power, and when that is reached we pile on coals in vain. In building a furnace, it adds to its efficiency to slant it upward inside the bars, say 1 foot in 6, until the upcast shaft is reached.

In the mines of this State the quantity of air moved by a properly constructed furnace ranges from 2,000 to 6,000 cubic feet per minute for every foot of breadth of fire. The depth of the ventilating shaft, its freedom from water, the sizes of the air-courses of the mine, the temperature of the outside atmosphere, all combine in determining the quantity of air which can be moved through a mine by furnace ventilation. In winter, as stated in the opening paragraph of this paper, the natural forces aid the ventilation, while in summer the natural forces oppose the furnace, like a steam-boat going up stream. In deep mines, like those in England, the natural current is in the direction of the upcast all the year round, because the mine air of deep mines is always rarer than the atmosphere on the surface; but, while in summer there is no opposing force to overcome, there is little assistance given, the temperature of the mine and surface air being so nearly equal in weight. In winter the natural forces and the furnace are in proportion to the difference of temperature of the mine and surface air. The practical power of the furnace is in proportion to the depth of the shaft, the power being as the ratio of the depth; hence, a shaft 400 feet deep will, with the same furnace, all other things being equal, move twice as much air as a shaft 100 feet deep. This practical fact is not as well understood as it should be, the common impression being that shallow mines move more air than deep ones, with the same ventilative power. Until within a few years ago, it was a rare thing to see a roomy, well-constructed furnace in a coal mine in this State, owing to the mistaken view of the influence of heated air in shafts.

Fan-ventilation, on the other hand, is more effective in shallow than deep mines, but fan-ventilation has only recently been applied in this State, and is not making as rapid headway as could be wished, mainly from the fact that the first cost of the fan is considerably greater than that of the furnace, and in drift mines it is as costly at all times,

because at drift mines the fan and engine require the attendance of an engineer, as the furnace requires an attendant. In a shaft mine the hoisting engineer can attend both engines, which is a saving of one man at the mine, besides the saving in the coal required to maintain a ventilating furnace. Whenever furnace ventilation is applied, the supply of air is liable to great irregularity by neglect of the furnace man; and the danger of fire, of which we have so many fatal examples, is ever present. Moreover, in mines where the furnace is placed at the bottom of the hoisting shaft, the guides, the ropes, and the timber of the shaft are subject to injury from the gases given off by the furnace. All these evils are obviated by the fan, in addition to the daily saving in fuel and attendance.

The best ventilating fans are constructed on the centrifugal principle, and those of the Waddle, Schiele, and Guibal patterns, as already stated, have attained high fame in England and the continental states of Europe. Guibal's is preferred to the rest, and is probably the best

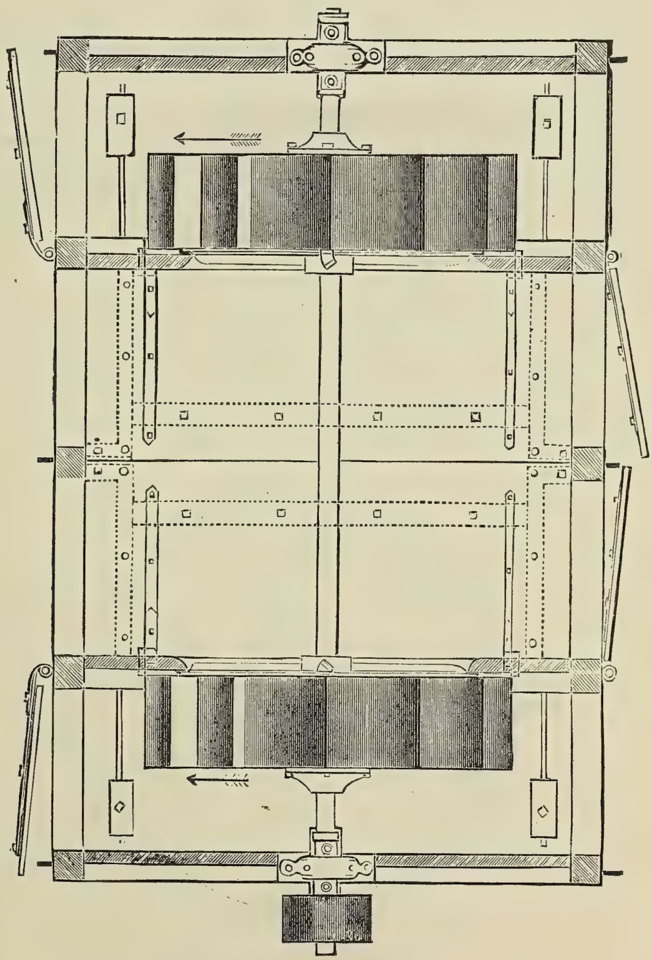


GUIBAL'S FAN

ventilating fan for the use of coal mines ever invented or applied in any country. This fan has a large diameter, some of those used at the deep and extensive mines in England ranging from 40 to 50 feet. The blades of the fan, eight in number, and 10 feet wide, are inclined backward, and the air is discharged through an adjustable shutter into an expanding chimney 20 feet in height; this fan, although more extensively applied

in the coal regions of England and continental Europe than all other fans combined, is yet mainly confined in this country to the anthracite region of Pennsylvania, because such costly and elaborate arrangements as attend its construction are not required to produce the limited currents of air which suffice for our shallower and smaller mines. From 250,000 to 300,000 cubic feet of air per minute are frequently produced by means of the larger Guibal fans in the mines of England.

The Champion fan, which was introduced into the mining regions of Ohio and other western States a few years ago, gives very satisfactory results. Wherever this fan has been introduced, mining engineers and mining bosses declare that they could not be hired to go back to the furnace as a ventilating power.



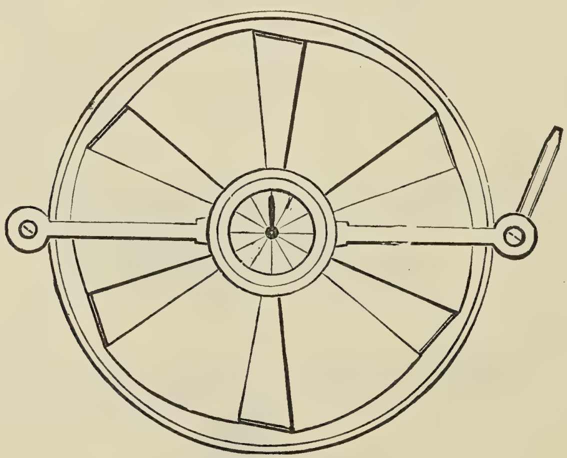
CHAMPION FAN.

CHAMPION FAN.

The larger the air-ways of a mine are made the greater the quantity of air is circulated with the same ventilating power; for the current is retarded in its progress by the friction which it encounters from rubbing against the sides, top, and bottom of the air-course. As it is not practicable to have large air-ways, owing to the difficulty and expense of maintaining them, it serves the same purpose to split the current into several parts, which, by reducing the velocity of the parts, reduces the frictional resistance to which they are exposed, and so, on the whole, produces a greatly increased current of air. The advantages of splitting air were well illustrated by Mr. John J. Atkinson, Government Inspector of Mines, in a paper read before the North of England Institute of Mining Engineers, and published in vol. III of the transactions of the Institute.

He shows that with a constant ventilating power, 16,198 cubic feet of air in one column will produce 70,884 cubic feet, in 5 equal and similar parts; 94,850 cubic feet, in 10 equal and similar parts; 99,722 cubic feet, in 15 equal and similar parts; 101,132 cubic feet, in 20 equal and similar parts.

Owing to the resistance offered by the shafts, says Mr. Atkinson, we dare not have more than a limited number of splits in a mine, because, although each split adds to the total quantity of air in circulation, still in each separate split the quantity ultimately becomes less and less.



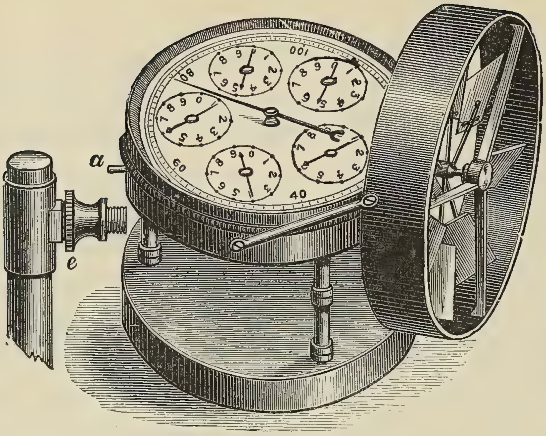
BIRAM'S ANEMOMETER.

The plan of splitting the air is not followed to any extent in the mines of this State. The pits are so shallow that it costs less to sink a new air-shaft at the interior of the workings than to provide any elaborate system of ventilation.

The manner of measuring the current of air circulating in mines is simple and speedy. Biram's and Castello's anemometers are the instruments in general use. Biram's 4-inch instrument reading to 100 feet is largely used by mining bosses. The anemometer self-registers the speed of the current. The vanes are so constructed that they revolve by the current of air impinging upon them. A point is selected in the air-course where the whole column of air passes; the instrument is held up in the current, and its speed is indicated by the rotary motion of the index hand or pointer of the dial-plate, which reads to single feet. One revolution of the pointer records 100 feet. The instrument is usually held in the air-way a single minute; it indicates, say 340 feet per minute, and the air-way is $6\frac{1}{2}$ feet high and 9 feet wide; the quantity of air in circulation per minute is found by multiplying the speed of the current by the sectional area of the air-way, which in this case would be 19,890 cubic feet of air per minute—the sectional area of the air-course being $58\frac{1}{2}$ feet, which, multiplied by 340, gives the above result. This is a current strong enough, if properly distributed, to ventilate any mine in the State.

In taking measurements with the anemometer, an allowance has to be made for the friction of the instrument, which is equal to 17 feet per 50 feet, 8 feet per 100 feet, 4 feet per 200 feet, 3 feet per 300 feet, 2 feet per 400 feet. The speed of currents varies from 100 to 400 feet per minute in mines, according to the ventilating power in use. A current exceeding 400 feet per minute in speed is not desirable; it blows out the miner's lamp, and chills his body. Currents of this speed are only found along the main air-courses of the mine. The complaints which arise from too strong currents of air are like angels' visits, few and far between.

Castello's anemometer or air-meter is made on the same principle as Biram's. It is smaller and more easily injured. Some of these air-meters have a minute sand-glass attached, which is a great convenience in taking accurate measurements.



CASTELLO'S ANEMOMETER.

Approximate measurements are made by miners by flashing gunpowder, and noting with a watch the speed with which the smoke moves along the air-way of the mine. A lighted lamp is sometimes used, the miner moving along the air-gallery, and keeping the light in a perfectly perpendicular position, noting the time required to pass to a given point. Both of these methods are the same in principle. The experiments can only be made along a straight gallery of uniform area. The distance measured off is usually from 100 to 200 feet. The lineal feet of the air-way is ascertained, which, multiplied by 60, the number of seconds in a minute, and divided by the number of seconds of time in which the powder smoke moved or the person traveled the measured off distance, gives the amount of cubic feet of air per minute in circulation.

CHAPTER V.

By Edward Orton.

THE IRON ORES OF OHIO,

CONSIDERED WITH REFERENCE TO THEIR GEOLOGICAL ORDER AND GEOGRAPHICAL DISTRIBUTION.

The geological series of Ohio begins with rocks of Lower Silurian age, and extends well toward the close of carboniferous time. Iron ore is mined in but one of the ten or more leading formations into which the scale is divided.

In the Lower Silurian rocks of the State no notable accumulation of iron, except the sulphide, is found.

In the Clinton limestone of Upper Silurian age, there is a moderate development of the "fossil ore," for which this formation is famous. The Clinton ore has been found in three counties of Southwestern Ohio, viz., Clinton, Highland and Adams. It has been mined in but one, viz., Clinton, and there but on the smallest scale. A small furnace was built on Todd's Fork, a few miles northwest of Wilmington, many years ago, upon the outcrop of the Clinton limestone, which carries at this point a few feet of lean, calcareous ore. The details of the experiment have not been recovered, but it is certain that a little iron was produced by the furnace in its brief history. It made but a single blast.

The ore is quite in keeping with the general character of this anomalous and remarkable deposit. It is a red hematite, sometimes consisting of flattened grains, and sometimes replacing and intermixed with a highly fossiliferous limestone. Red rocks are as a rule barren of fossils, the presence of the salts of iron in water to any considerable amount being fatal to most forms of life, but in the Clinton ore we have a rock abounding in the characteristic fossils of Upper Silurian time, and yet carrying enough red oxide of iron to make it one of the valuable ores of the country.

The ore of which we are now treating is lean. The rock is, in fact, a limestone rather than an ore. In Clinton county it is remarkably rich in fossils; a number of species new to science have been derived from the very outcrop which was worked for ore. Among the fossils that it contains, in addition to the coarser and stronger forms, there are lace corals in excellent preservation, and crinoidal remains in great profusion. Part of the ore bed is in reality a crinoidal limestone. These facts are unexplained, but similar facts are found in connection with the ore of this formation through its whole extent, from Lake Ontario to Alabama.

In the southern part of Highland county, near Sinking Springs, and in the adjacent portions of Adams county, a heavier and more promising outcrop of the ore occurs. Reference is made to it in the Report of Progress for 1870, page 268. Natural exposures of the series are found here, which contain beds of ore of fair quality, from 1 to 2 feet in thickness, but in the absence of exploration, positive conclusions as to the steadiness and value of the deposits are not warranted. Such facts as can be observed, suggest a doubt as to their persistency. A partial analysis of the richer portions of the ore by Professor Wormley gave the following results:

Carbonate of lime	48.00
Metallic iron	30.00
Phosphoric acid	1.28

No great expectations need be entertained as to this ore in Ohio as a source of iron, but there is a possibility that some valuable beds may yet be found.

In the Niagara limestone of Adams county a small amount of iron ore exists. It occurs in depressions upon the upper surface of the limestone, buried in the clays that result from the decomposition of the bedded rock. When these clays are removed, masses of a soft limonite, resembling bog ore in structure, are found. From a single pocket, 8 or 10 feet deep, and 12 or 15 feet in diameter, several tons have been taken out. The Brush Creek Furnace was built in the valley of the same name in the early days of iron manufacture in Ohio, to work these newly found deposits. As might be expected from so precarious a supply, the furnace was soon stopped for want of ore. There is no reason to believe that this source of iron will ever again be brought into use.

No iron ore occurs in the next succeeding member of the Ohio scale, viz., the Lower Helderberg limestone, nor is any known in either the Devonian limestone or the Devonian shale, but springs issuing from the latter sometimes form considerable deposits of bog ore. In the great Waverly Group of Sub-carboniferous age, more favorable conditions for iron production occur, and we begin to find ore segregating from the clays and shales in distinct horizons. None of these accumulations, however, is regularly mined in the State, and none, so far as known, has ever been mined, except in occasional trial pits. The seams are at once uncertain, thin, and of doubtful quality. The only localities where any attempts are made to obtain ore from the Waverly Group is in the vicinity of the westernmost furnaces of the Hanging Rock district. Here all horizons that promise supply are tested, and, among others, these unlikely sources of iron are occasionally tried.

The Sub-carboniferous limestone, which is sparingly developed, and more sparingly worked in Ohio, carries a block ore of approved quality on its upper surface, and occasional kidneys of ore in the clays above it. This ore has been worked to a small extent in Scioto, Jackson and Perry counties in connection with the limestone which supports it. Wherever the latter has been worked for furnace flux, a little of the ore has been brought out with it, but at the present time other limestones have entirely supplanted these thin and impure beds of Sub-carboniferous age. That the ore is not a strong or persistent body is evident from the fact that all production of it ceases with the working of the limestone.

The Carboniferous Conglomerate that comes next in the scale is an iron bearing horizon, to a limited extent. There is often a sheet of ore of a few inches in thickness intermixed with the pebbles of its upper surface. The coarse and worthless ore, once mined at Scioto Furnace under the name of the Guinea-fowl ore, belongs to the Conglomerate horizon, but no valuable deposit has been found in this formation, and none is likely to be found.

The iron ores now mined in Ohio belong without exception to the division next reached in ascending the geological series, viz., the Lower Coal Measures. The discussion of this group of ores will occupy the present chapter. Before entering upon it, however, brief mention will be made of the two remaining sections of the Ohio scale, viz., the Barren Measures and the Upper Coal Measures, which will be treated together.

The Barren Measures contain a notable quantity of iron, as the red color of the heavy beds of shale that form so conspicuous a part of them indicates, but the same fact points to the diffusion of the iron in a valueless form. The same general statement can be made for the Upper Coal Measures. There is occasional concentration of ore in connection with limestone and clay deposits throughout the series. When the Cambridge limestone, for example, is worked for furnace flux, a thin plate of good ore is often found to cover it, but the ore is never sought by itself. In some cases there is a blending of ore with the earthy limestones of the Freeport or Brush Creek type, which forms beds of several feet in thickness, and which has good weight, but which generally runs so low in iron, and so high in silica as to be without value. They seldom reach 30 per cent. of metallic iron. Many attempts have been made to mine and work these ores, which occur in several distinct and fairly persistent horizons. One of these deposits will be treated briefly on a subsequent page.

In one case, at least, a charcoal furnace was built in Southern Ohio that was to rely upon one of these voluminous Barren Measure ores, but the life of the furnace was brief. After a single blast of short duration, the furnace passed into one of the "picturesque ruins" to which so many of the charcoal iron furnaces of the Appalachian field have heretofore been doomed to come. One ore of a different character that belongs to both the Barren Measures and the Upper Coal Measures deserves to be mentioned here. In the red clays that lie near or that sometimes replace the limestones of these series, nuggets of red hematite of high grade are often found. They range in size from pellets up to masses weighing 50 or 75 pounds. Being of high specific gravity and insoluble, they accumulate in the water-courses and on weathered outcrops, and thus suggest a greater abundance of ore than there really is. In only one district of Ohio have they been found gathered into anything like a seam that would justify mining. In one or two townships of Noble county, at a horizon about 150 feet above the Barnesville coal seam (No. 8c) there is a good promise of deposits that could be worked with profit if transportation were available. The clay that holds the ore is but a few feet in thickness, and the aggregate of the ore makes a respectable part of the entire thickness.

In most cases, it would require the sifting of many feet of clay or

shale to secure an average of an inch of ore. The quality is of the best. The ore will yield 60 per cent. and upwards of metallic iron, but in practically the whole field that these nodules occupy, the quantity is too small to justify working under the present conditions of iron manufacture. This ore, in other words, has no present value, and it does not seem probable that it can ever be profitable to mine it. Each new observer that comes into the field, however, will be impressed with its intrinsic excellence, and will need to satisfy himself by independent observations that it does not exist in such a condition as to warrant mining before he will be willing to abandon so promising an addition to the iron making materials of Ohio.

There is not a single seam of ore above the Mahoning sandstone that is regularly mined in Ohio at the present time.

Classification of the Ores of the Lower Coal Measures.

As has already been stated, all of the native iron ores of the State which are turned to present account for furnace use are derived from the Lower Coal Measures. One or two trifling exceptions have been already noted in the cases of the block ore borne by the Sub-carboniferous or Maxville limestone and the rough ore that caps the conglomerate, but the statement scarcely requires qualification for such exceptions as these.

The ores of the Lower Coal Measures were all accumulated under the same general conditions, i. e., as carbonates of iron in the marshes and swamps of the period to which they are referred, but they have assumed several distinct forms which afford a convenient basis of classification.

They can be divided into the following groups:

I. The stratified or mechanically-formed ores.
II. The concretionary or chemically-formed ores.

The first group includes all those ores that bear the marks of having been accumulated in water, or at least in successively formed, horizontal sheets, after the fashion of ordinary sediments. The carbonate of iron that they contain has of course had a chemical history similar to that of the same mineral in other ores, but the arrangement of the carboniferous or shaly matters with which the iron is associated is due to stratification. These ores are variously known as

blackband ores, clayband ores and "flag" ores. They contain, as a rule, a smaller percentage of iron than the other ores of the series, but compensation for their poverty is made in whole or in part by their greater volume and also by the character of the foreign matter sometimes associated with them. There is often enough carbonaceous matter in the seam to effect the calcination of the ore, and by the expulsion of the carbonic acid of the ore and by the combustion of the organic matter of the seam, the proportion of metallic iron is raised from 25 to 50 per cent. In volume, as compared with the other ores of the series, they may almost be said to give feet for inches, the maximum that they attain being 19 feet, and the working thickness of large areas rising to 6 feet and over.

The ores of this class are worked at three or more distinct horizons of the Lower Coal Measures of Ohio, and are of great economic importance.

The second group includes those ores that owe their present forms to the obscure agency to which we give the name of concretionary force, a force which is allied to chemical force to this extent, that it gathers up and unites the previously scattered atoms of one or more chemical compounds. Of this group there are three distinct subdivisions, which are named below:

(*a.*) Kidney ores.
(*b.*) Block ores.
(*c.*) Limestone ores.

The ores in which concretionary force is most distinctly shown are those known as *Kidney Ores.* They consist of masses of impure carbonate of iron, often rudely discoidal or ellipsoidal in form, and always bounded by curved surfaces. As a rule, they are composed of concentric layers or shells which are made very distinct by weathering. They sometimes have hollow cavities within, after weathering, and sometimes enclose masses of clay. Some of them, however, are crystalline at their centers, containing calcite or barite, or occasionally sulphide of zinc. They are generally quite close grained and heavy, when under good cover. They range in size from an inch to a foot in diameter. They are distributed in the beds of shale or fire-clay that make up so large and characteristic a portion of the coal measure strata, and from which their materials have been segregated. Sometimes they are gathered into distinct horizons, which the miner can easily and economically

follow, and sometimes they are so sparsely distributed that though the aggregate amount of ore in a bed of shale or clay is considerable, it will not pay for working.

In quality, these ores hold a good rank. They are often very kind and easy to smelt. The weathered kidneys are almost always so. The unweathered masses are frequently too close and stubborn for use in charcoal furnaces. They contain from 35 to 50 per cent. of metallic iron.

There are 5 or 6 pretty well marked horizons of kidney ore, some of which are quite persistent and widespread.

The *block ores* are so called from the fact that they are found in horizontal and almost continuous sheets of uniform thickness, but these sheets are of chemical not mechanical origin. They range in thickness from one or two inches to one or two feet, but the ores that are worked are mostly between 4 and 8 inches in thickness. The separate blocks have the same general structure as the kidney ores last described. They show their concretionary origin in the concentric layers that weathering reveals. These blocks are often fitted to each other like the separate blocks of a tesselated pavement.

They bear a peculiar relation to the coal measure limestones. Without exception, the leading block ores of the field are borne by these limestones, or else, the ores seem to replace and substitute them. They deserve to be called limestone ores from this point of view, and they are so called in some localities, but in Ohio, this name is mainly reserved for other phases of iron accumulation.

The block ores of our scale are often mellow and excellent. The weathered ores average a little more than 40 per cent. of metallic iron as a rule.

There are three chief horizons of these ores, and two of them are remarkably persistent, stretching with the limestones that bear them entirely around the field.

The ores that are known as *limestone ores* present two distinct phases. The name is mainly confined to the Hanging Rock district of Southern Ohio, where it is applied to one well-known and very valuable seam, viz., the ore borne by the Ferriferous limestone of the general scale. The designation "limestone ore" is specific in this portion of the State, being exclusively applied to this seam. The ore overlies the limestone, sometimes graduating insensibly into it, and sometimes

separate and distinct from it, but lying in close proximity. Above the main sheet of ore, kidneys are generally to be found scattered through the clay. A common and very characteristic form of the unaltered ore of this horizon is found in the so-called gray ore. It consists of minute grains of carbonate of iron, buried in a silicious clay. This form does not blend with the limestone. The most valued form of the ore, especially for use in charcoal furnaces, is the limonite that has resulted from the weathering and transformation of the original carbonate.

A second phase of limestone ore, but not usually recognized by that name, is the replacement of the buff limestones of the Freeport type with carbonate of iron to a greater or less extent. These ores are very uncertain in character, changing from ore to limestone on short notice. On their outcrops they are frequently ores of fair grade, while under cover they are simply ferruginous limestones. The impure limestones of this group are frequently nodular, lying in detached masses in their clays, and when these are transformed into limonites as far as their iron will allow, they pass for kidney ores, but they do not show the same history as the ores to which this name has already been assigned.

The ores of the Lower Coal Measures will all be included under one or another of the forms now described, but distinct attention must be called to a line of facts which has several times, in the course of this discussion, been mentioned incidentally. These ores, while originally carbonates of iron in every case, have been transformed along their lines of outcrop, and often under considerable cover, into hydrated peroxides or limonites. In many instances the transformation has been very thorough, the form, volume, specific gravity, texture, and color of the ore being changed in the process. The change is always in the line of improvement of the quality of the ore.

GEOLOGICAL ORDER OF THE IRON ORES OF OHIO.

I. The Stratified Ores.

The ores of this list, consisting mainly of blackband, but also including some clayband and some undescribed forms known by local names, belong to the three distinct horizons named below:

1. Upper Freeport coal.—Main blackband horizon. Also, clayband ores.
2. Forty feet below Lower Mercer limestone.—Confined to Southern Ohio. "Flag ore," Boggs ore."
3. Sharon coal.—Blackband ore; mainly in Northern Ohio.

There are local deposits of blackband or other stratified ores outside of these horizons, but no really valuable beds have yet been found among them. Some of these local accumulations will be noticed on subsequent pages. It is not probable that any persistent *horizons* of iron ore have been missed in the Lower Measures, but we may reasonably expect, through accumulating skill, to be able to work at some future time beds that we now reject, and there is good reason, also, to believe that many valuable basins of ore remain to be discovered at the several horizons named above.

II. The Concretionary Ores.

a. *The Kidney Ores.*

These ores as now worked are derived from the several horizons named below:

1. Upper Freeport limestone—In Southern Ohio.
2. Lower Freeport limestone—In Southern Ohio.
3. Kittanning shales—Between Kittanning coals.
4. Ferriferous limestone and Clarion coals.
5. Putnam Hill limestone—In Southern Ohio.

b. *The Block Ores.*

The ores of this class are derived from the several horizons named below:

1. Putnam Hill limestone—In Northern and Central Ohio.
2. Upper Mercer limestone.
3. Mercer shales—Between Mercer limestones.
4. Lower Mercer limestone.
5. Maxville limestone—Sub-carboniferous.

c. *The Limestone Ores.*

The limestone ores are referable mainly to one horizon, viz., that of the Ferriferous limestone. There is in reality but one ore from this

class that attains any great importance in iron making in Ohio, and this one stands at the head of the list of all Ohio ores. It is known as "Limestone ore" in the southern counties, and as the Baird ore in Hocking and Perry counties. Upon it the charcoal iron industry of Ohio has been established and maintained.

The places of these several ores in the geological scale have now been pointed out. It will be seen that they are distributed throughout the entire Lower Coal Measure series, from bottom to top, being found at not less than 12 distinct horizons, which are shown below:

Upper Freeport coal.
Upper Freeport clay.
Upper Freeport limestone.
Lower Freeport limestone.
Kittanning shales.
Ferriferous limestone—2 or more separate deposits.
Putnam Hill limestone.
Upper Mercer limestone.
Interval between Mercer limestones.
Lower Mercer limestone $\begin{cases} \text{Above.} \\ \text{Below.} \end{cases}$
Interval between Mercer and Sharon Groups.
Sharon coal.

GEOGRAPHICAL DISTRIBUTION OF THE IRON ORES OF OHIO.

The ores of the first section, viz., the stratified ores, are worked at the present time in the seven counties named below:

Trumbull,	Tuscarawas,
Mahoning,	Perry,
Stark,	Scioto.
Carroll,	

The blackband of the Sharon coal horizon is worked in Trumbull and Mahoning, and to a trifling extent in Scioto county. The blackband of the Upper Freeport coal horizon is worked on a large scale in the four remaining counties of the list.

Kidney ores are mined at the present time in the seven following counties, viz.:

Columbiana,	Jackson,
Stark,	Gallia,
Tuscarawas,	Lawrence.
Vinton,	

Those of the first three counties are derived from the Kittanning and Clarion horizons mainly; those of Vinton and Jackson from the Clarion and Putnam Hill horizons, and those of Gallia and Lawrence come from the Kittanning and Freeport horizons. Mahoning county formerly produced a small quantity of Kidney ore from the horizon of the Sharon shales.

Block ores are now mined in the eleven counties herewith named:

Mahoning,	Hocking,
Stark,	Vinton,
Tuscarawas,	Jackson,
Muskingum,	Scioto,
Licking,	Lawrence.
Perry,	

In Mahoning and Stark, the production is very feeble, or has altogether ceased. It was based on the ores borne by the two Mercer and the Putnam Hill limestones, respectively. Tuscarawas, Muskingum and Licking rely on the same sources. The Putnam Hill horizon does not furnish a block ore beyond the last-named limit. Perry and Hocking counties mine only the Lower Mercer block ores; Vinton, Jackson and Scioto depend on the three Mercer horizons, to which Jackson adds a trifling amount of block ore from the sub-carboniferous horizon. Lawrence makes use of a considerable quantity from the Mercer horizons.

The limestone ore is mined on a large scale in the first four counties named below. In the last two the production is less important:

Lawrence,	Vinton,
Gallia,	Hocking,
Jackson,	Perry.

From these statements it will be seen that iron ore is now mined in 15 counties of Ohio at the 12 distinct horizons named above.

The names of the counties are appended in order, from north to south:

Trumbull,	Perry,
Mahoning,	Hocking,
Stark,	Vinton,
Columbiana,	Jackson,
Carroll,	Gallia,
Tuscarawas,	Scioto,
Muskingum,	Lawrence.
Licking,	

A brief review of these several counties named in the preceding lists will now be made with reference to their supplies and production of ore.

1. Iron Ores of Trumbull and Mahoning Counties.

The only ore of these counties that possesses any present importance is the blackband of Mineral Ridge and vicinity. The geological relations of this seam have already been shown on page 174 of the present volume. The facts pertaining to its discovery, and to its first use in furnaces are also given in chapter IV, p. 320.

The field in which it occurs is quite limited, and the deposit is now verging to exhaustion. The facts in regard to its mode of occurrence and general conditions are well known, and it has not therefore seemed incumbent upon the present survey to spend time upon this deposit.

An analysis by Wormley, representing the general character of the ore, is repeated here from volume III:

Specific gravity	2.49
Volatile matter	30.50
Silicious matter	11.84
Carbonate of iron	43.26
Sesquioxide of iron	9.94
Alumina	Trace.
Oxide of manganese	1.00
Phosphate of lime	Trace.
Carbonate of lime	1.87
Carbonate of magnesia	2.03
Sulphur	0.18
Total	99.62
Metallic iron	27.12
Phosphoric acid	Trace.

A single analysis was also made for the survey. The sample came from the John Henry mine, of Austintown township:

Analysis of Mineral Ridge Blackband.—John Henry Mine. (*Lord.*)

Silica	7.15
Iron sesquioxide	31.26
Iron sulphide	2.52
Alumina	4.62
Lime	1.36
Magnesia	1.31
Oxide of manganese	0.55
Phosphoric acid	0.33
Sulphur	1.44
Volatile and combustible matter	47.56
Moisture	1.85
	99.95
Metallic iron	24.40
Phosphorus	0.145
Sulphur	1.44

A small amount of block ore has been mined in Mahoning county in years past, at the horizon of the Lower Mercer limestone. It has been obtained chiefly from Austintown, along the line of the Niles and New Lisbon Railroad. The block is thin, but the quality, as usual, is good. There is no present nor prospective importance to this seam in this portion of the State.

The same remarks will apply to the kidney ore of the Sharon shale horizon. It has been mined at a number of points in the Mahoning Valley in former years, but little or none of it is now taken.

The iron-making industry of the Mahoning Valley was established on the block coal that is found here, the character of which fits it for use in the furnace in the raw state. In the earlier days of the furnaces some account was made of the thin seams of native ore that are available, and the seams already named were brought into use at that time, but both native coal and native ore have of late been supplanted by foreign rivals. Connelsville coke and Lake Superior ores are the almost entire dependence of the Mahoning Valley furnaces to-day.

2. Iron Ores of Columbiana County.

The ore production of Columbiana county stands by itself among the mining interests of the State. Not a pound of ore is taken directly from the horizons that supply it, but the ore mining of the county is altogether *placer* mining. The gravel beds that fill the valley of the Middle Fork of Little Beaver constitute the present available ore deposits of the county. These gravel beds are dug over and sifted, and the ore is selected from the other materials by hand picking.

The ores of this county all belong to the class of kidney ores. They are chiefly derived from two horizons, but additions are made from two others, to a small extent. The main horizons are (1) the Kittanning shales, *i. e.*, the shales between the Middle and Lower Kittanning coals, and (2) the Ferriferous limestone. The subsidiary sources are scattering kidneys that are found with or near the Freeport limestones, both of which are well developed in the county.

These horizons can be arranged in tabular form, as follows:

Upper Freeport limestone.	
Interval	30 to 50 feet.
Lower Freeport limestone.	
Interval	70 to 90 feet.
Kittanning shales.	
Interval	25 to 40 feet.
Ferriferous limestone—Coal No. 3 at Leetonia.	

The two main horizons will be recognized as among the most important and widely extended sources of ore in the Lower Coal Measures. The first named is in fact the largest source of kidney ore in the State. It produces the "shell ore" of Tuscarawas and Stark counties, the Snow Fork kidney of the Hocking Valley, the Black kidney of Lawrence county, and the Red kidney of Northern Kentucky. The second horizon is by all odds the most important single source of iron in the Lower Coal Measures. It is the Clarion and Wampum ore of Western Pennsylvania, on which the old charcoal iron manufacture of that State was based. It is the limestone ore of the Hanging Rock district, and the Baird ore of the Hocking Valley, on which the charcoal iron manufacture of Ohio was and is almost entirely dependent. In both Pennsylvania and Ohio, however, the ore derived from this source is no longer confined to charcoal iron-making, but it has become

a prominent factor in the supply of the stone-coal furnaces of the last decade.

This ore does not exist in characteristic form in Columbiana county. The limestone, it will be remembered, is itself weak and often wanting in this district, but the iron which belongs to the horizon does not fail. The form which it takes has been modified by the absence of the limestone, and instead of segregating at one definite line, viz., the surface of the limestone, and thus forming a "limestone ore," it is diffused in kidneys, often of large size, through a number of feet of shale. These scattered kidneys it would not repay the miner to follow in their native beds, but when accumulated and concentrated in the valley deposits after the fashion of other placer deposits, it has been found economically possible to reclaim them for furnace use. A considerable part of the Columbiana county ores, it will thus be seen, belongs to the Ferriferous limestone horizon.

The kidneys between the Kittanning coals are gathered into a more definite horizon, and it may be possible to find localities in the county in which they can be worked with profit in their native beds, as in adjoining counties. So far, however, no such accumulations have been reported, and their whole production is confined to the placer accumulations of the valley of the Middle Fork.

The ore exists in all cases as weathered ore. The crust, at least, of all the kidneys has been converted into limonite by atmospheric agencies. These ores are within reach of such agencies in the valley deposits, which are freely permeable, and it is also quite possible that a part of the process of oxydation was carried on before the kidneys were buried here. These accumulations stand for the work of ages, the separate blocks having been mined out by the erosive agencies of the drainage streams through many thousands of years. Even if the work of accumulation should be limited to the time that has elapsed since the Glacial epoch, a vast period would be available for this history, but there does not appear to be sufficient reason for restricting the work to post-glacial time.

It is believed that the best of these supplies has already been taken. A large acreage is exhausted, and no considerable territory remains to be attacked, at least under the same favorable conditions that have been found hitherto. The excavations are carried as low as 20 feet in

extreme cases. Generally they do not go down more than half this distance.

The field already worked lies along the West Fork Valley from a little below Teegarden's Mills as far south as Elkton. The southern territory has proved the best. It was not found possible to determine the percentage of yield in the worked deposits, nor to refer the kidneys as they occur to their several sources. Both these questions admit of answers, but the answers would require more time than was available.

The character of the ore is excellent, as is to be expected from the horizons to which it belongs. Its use has been mainly confined to the Leetonia furnaces.

3. Iron Ores of Stark, Carroll and Tuscarawas Counties.

Three varieties of ore, viz., blackband, kidney and block, have been already shown to be mined in the area now to be considered. The order in which they are named is the order of their importance, but the first is the great center of interest and value, and the last is of insignificant proportions, and moreover is mined only in one of the three counties named, viz., Tuscarawas.

a. Blackband and Mountain Ore.

The blackband ore of this area is the most important source of iron in Northern Ohio. It is the second ore in general value in the State, ranking below the limestone ore of the Hanging Rock district alone in this respect. With the last-named ore it disagrees in almost every particular of geological occurrence. The limestone ore is both steady and persistent, covering hundreds of square miles almost continuously with its thin but excellent sheet. The blackband is extremely capricious in its occurrence, and treacherous in its development. It forms the cap of scarcely more than 50 hills, scattered through three counties, and in these hills it ranges from a maximum of 19 feet to zero, an acre or two being often sufficient to accomplish the whole range of changes.

Throughout this field it everywhere deserves its name of blackband. There is almost always a foot or two of coal, generally poor in quality, underlying it, and thin streaks of coal generally extend through the ore itself. But whether coal is present in the body of the ore or

not, carbonaceous matter is never wanting. There is nearly enough of this substance generally to calcine the ore. The ore is consequently always black, or at least dark in color. Its specific gravity for the same reason is light for an iron ore, ranging generally from 2.3 to 2.5. When calcined, the figure that represents its gravity is nearly a unit higher than the figures above given. The banded structure is very distinct in all portions of the ore, as much so as in ordinary bituminous shales.

The raw ore ranges from 20 to 30 per cent. in metallic iron, the calcined ore from 45 to 55 per cent.

Above the blackband proper there are frequently found other large accumulations of ore, which by strict classification would need to be considered in other divisions, but which can be dealt with to best advantage in the present connection. The mountain ore, so-called, is one of the forms of limestone ore to which attention has already been directed, where carbonate of iron replaces locally the carbonate of lime in a stratum of the Freeport type. Many kidneys of ore also occur at the same general level.

The geological place of the blackband has already been assigned (see page 71). It is borne by and is part of the Upper Freeport coal seam. It is found only on the outer margin or outcrop of the formation, thus far, though notable accumulations of iron can often be found with the seam as it descends towards drainage. This marginal development of the ore needs to be distinctly recognized. The usual element to which we refer in establishing the sections in which the blackband occurs is the Middle Kittanning coal, or No. 6 of Tuscarawas county. Counting from this, the average interval is about 125 to 130 feet. The measured intervals in different portions of the field are as follows: 110 ft., 114 ft., 117 ft., 118 ft., 120 ft., 120 ft., 125 ft., 130 ft., 132 ft., 143 ft., 145 ft., 147 ft., 148 ft. and 150 ft. In no single case does the measure fall to 100 feet. A difference of 20 feet can often be found for the level of the ore itself in different portions of the same basin. The ore generally lies on an uneven floor, and frequently in well-defined and quite limited basins.

The first display of blackband as we enter this district from the east and north is found in the northeastern corner of Osnaburg township (see map on page 65). An area of small extent, perhaps not an acre, is found capping a hill with not a dozen feet of cover at the highest point. It is owned and worked by the Grafton Iron Company, of Lee-

tonia. The ore has a maximum thickness of 14 feet. Coaly streaks are distributed through the whole mass. Much of it is considerably weathered, and it splits into thin lamina, but the whole seam is taken for furnace use, and taken at the present time without calcination, being used raw in the furnace. The deposit is nearly exhausted. The interval from the Middle Kittanning coal to the blackband is here 118 feet, as obtained by a single measurement. A single analysis gives the following result:

Blackband from Grafton Iron Company's Mine—Osnaburg Township. (Average of 15 Feet.) (*Lord.*)

Silica	13.26
Iron protoxide	1.80
Iron sesquioxide	41.08
Alumina	7.93
Manganese oxide	1.42
Lime	2.07
Magnesia	0.65
Carbonic acid	3.47
Phosphoric acid	1.362
Sulphur	0.175
Water and organic matter	25.23
Moisture	2.13
	100.57
Metallic iron	30.15
Phosphorus	0.592
Sulphur	0.175

A small area has already been entirely worked out by the Burton Ridgway Company, of Massillon, from the intersection of sections 11, 12, 13 and 14, on a farm now owned by Thomas Tinkler. The maximum thickness of the ore, as reported by Mr. Tinkler, who superintended the mining, was 18 feet and 11 inches. This is the highest measure recorded in the field. This body was also without cover, and the whole hill top was carried away in the workings.

In Paris township, north of Robertsville, three small deposits have been worked for a number of years, at intervals. The ore does not rank as high in these areas as at some other points. The ore hills are known as the McNutt, Wolf, and Shull banks, respectively. Their combined acreage is small. A considerable body of the ore is still left in these deposits.

In Sandy township, of Stark county, no valuable beds of the ore have yet been discovered. The horizon is very clearly displayed at many points, and on several farms the Upper Freeport coal has been worked on a small scale. On the land of David Stull, for example, on the west side of the township, a large body of lean ore. overlying the Upper Freeport coal, was mined and calcined many years ago, but the ore was pronounced unfit for iron manufacture, and it still lies in the kilns. Several other attempts have been made to find the ore in this township, but, though several banks have been opened, none of them has furnished ore of proper quality.

Better fortune has attended the development of this horizon in the adjacent township of Rose, in Carroll county. Three separate but closely contiguous hills have been found to hold blackband ore of fair quality. They are situated on the Rhinehart, Creighton, and Newhouse (formerly Gibler) farms, respectively, and are all embraced in section 24. The interval from the Middle Kittanning coal, which is mined at the foot of the hills in which the ore banks are found, is 130 feet for the Rhinehart farm, and 147 feet for the Creighton farm. The Rhinehart bank has been entirely worked out. A little ore is left in the other areas. At the Newhouse bank it is 3½ feet thick Considerable ore has been mined here, but it was pronounced too lean, and was consequently abandoned. Samples were taken from this rejected ore for partial analysis, the result of which is given below:

Analysis of Newhouse Blackband. (*Lord.*)

Silica	12.39
Metallic iron	25.65
Phosphorus	0.157
Sulphur	0.46

The figures show an excellent ore, that ought to be handled with profit in any furnace that is using blackband. There is certainly nothing in the analysis to justify the discarding of the ore. It is quite up to the average of blackbands in metallic iron, and it is much lower in silica than most ores of this class. The only question is whether the samples fairly represent the bank. They were taken with this specific object from the piles that were mined, but never removed from the ore bank.

The next deposits of ore in following southwestward are found in Tuscarawas county. This county is, by way of excellence, the blackband field of the State, and the seam is generally and justly known as the Tuscarawas blackband.

The map of the county that appears on page 257 indicates the positions of all the ore hills of the county. The observations already recorded in Stark and Carroll counties can be combined with these to show the area occupied by the seam (see map on page 65). It is confined in its characteristic development, according to present knowledge, to the townships of Osnaburg, Paris and Sandy, of Stark county; Rose, of Carroll county; and Sandy, Fairfield, Dover, York, Auburn, Jefferson, Salem and Oxford, of Tuscarawas county. A line drawn from the northeast corner of Osnaburg township to the northeast corner of Auburn township would mark approximately the western outcrop of the ore for the first portion of its extent. Such a line would be about 25 miles in length, and its direction would be nearly southwest. From the northeast corner of Auburn township, the field is continued to the southward, but the direction of its axis is abruptly changed. A line running from this point due south, and 20 miles in length, will mark the approximate western outcrop of the field in this direction. In both portions, a breadth of 6 miles, at right angles to the line of western outcrop, will reach every ore hill. The greatest developments of the ore are found in Auburn, Jefferson and Oxford townships, and these are represented in a subsidiary map which will presently appear.

Returning to the northern boundary of Tuscarawas county we find but little land in Sandy township high enough to receive the ore, but on at least one of these few points the ore is reported. On the farm of Wm. Gordon, one mile east of Mineral Point, the coal of the seam is 20 inches thick, and the blackband is developed also to some extent. As to its quality and quantity, there are conflicting statements. The hill has been sold or leased as an ore property, but the contract is now before the courts.

In Fairfield township two bodies of blackband are being mined at the present time, but a number of separate areas have already been exhausted, the credit for the discovery and first use of the ore belonging to this township (see vol. III, page 77).

The two tracts now furnishing ore are the Labb hill, near Zoar Station, and the Kelly farm, a little more than 2 miles south of the

former. The ore of the first is mined and used by the Tuscarawas Coal and Iron Company, of Dover; the Kelly ore is mined by a company from Massillon. This mine is under heavy cover, and the ore is wrought in rooms by regular methods. The seam ranges from 3 to 8 feet in thickness, and the probable average is 5 feet. It is in all respects a fine body of ore. It has been necessary thus far to follow the seam along the line of dip, and consequently the workings are constantly troubled with water. Both blackband and mountain ore are yielded by this mine, the proportions being two of blackband to one of mountain ore. The Riggle Hill, near by, has been entirely exhausted.

Extensive stripping has been done on the Labb farm, the height of the bank sometimes reaching 25 feet, but part of the ore is also gained by drifting. There is not a large body of the ore left.

The possible blackband territory of the township is quite extensive, and, though considerable exploration has been carried on by the drill and otherwise, it is not necessary to believe that the ore is all known at the present time.

But two small tracts of blackband are known in Dover township. There is not a large amount of land in the town that is high enough to catch the ore.

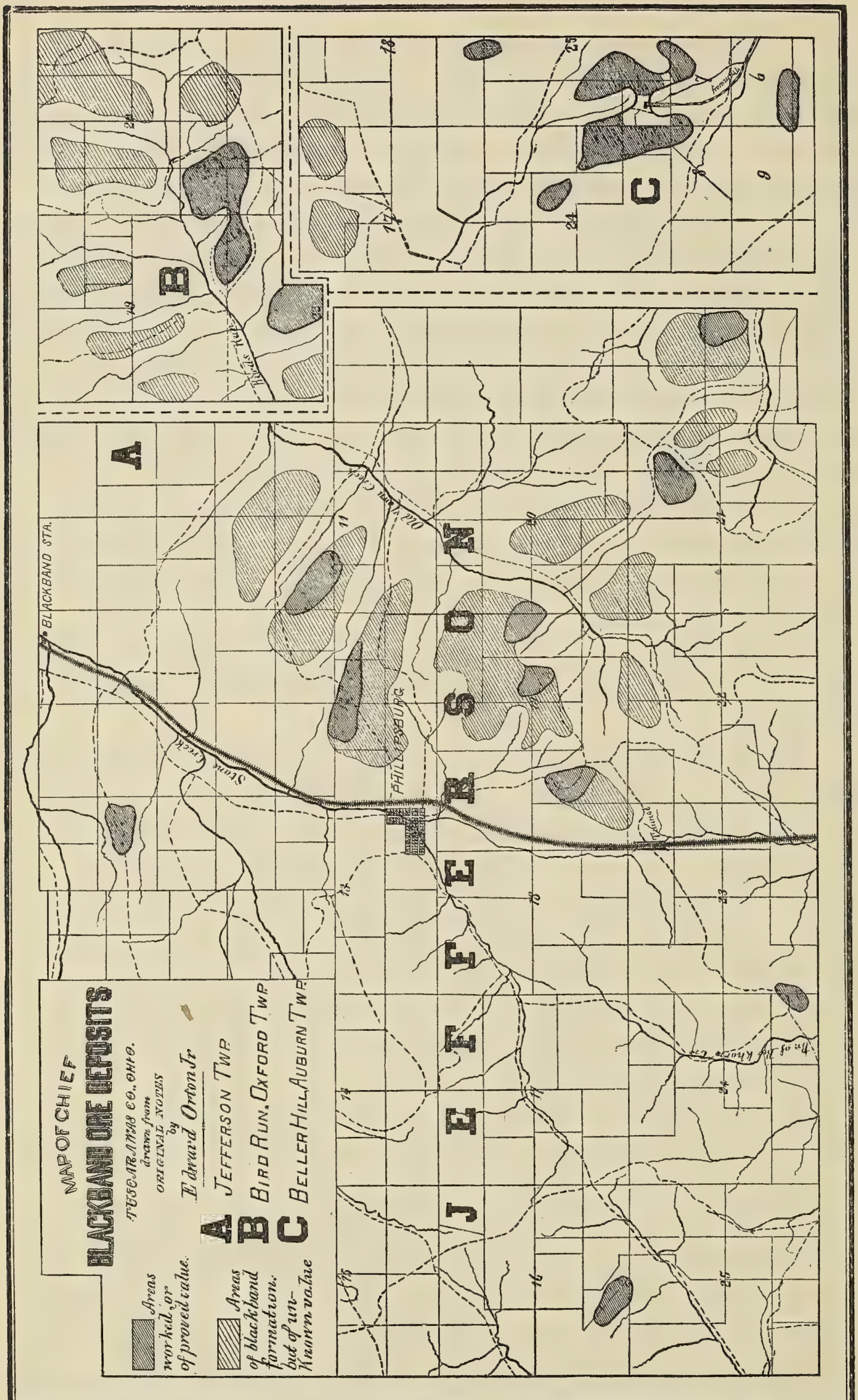
A mile south of Zoar Station, and nearly opposite to the Labb hill already described, the Tuscarawas Coal and Iron Company, of Dover, own a small tract of blackband that has not been fully developed. No mining is done in this seam in Dover township at the present time.

The two townships south and southwest of Dover, viz., Auburn and York, contain, or rather have contained, some of the noblest bodies of ore in the whole blackband field, but the ore has been chiefly mined out from York, all operations here having ceased. From Auburn, also, a large quantity has been taken, but a considerable acreage still remains, and the work of mining is going forward.

The chief banks in York township were the Bear hill, in lot 32, N. W. $\frac{1}{4}$; the Burkholder hill, lots 12 and 13, N. W. $\frac{1}{4}$; Winkler's and Shull's hills, section 16, and lots 5 and 6, N. W. $\frac{1}{4}$.

Considerable ore has been left in all of these deposits, but generally in such a condition that it can not be recovered with advantage. The earlier workings were without system, and were consequently wasteful.

There is still an area which is supposed to hold the ore, on lots 30, 33 and 35. It is high enough, and surface indications are counted favorable.


MAP OF CHIEF
BLACKBAND ORE DEPOSITS
TUSCARAWAS CO., OHIO.
drawn from
ORIGINAL NOTES
by
Edward Orton Jr
A JEFFERSON TWP.
B BIRD RUN, OXFORD TWP.
C BELLER HILL, AUBURN TWP.
Areas worked, or of proved value.
Areas of blackband formation: but of unknown value
BLACKBAND STA.
PHILLIPSBURG
JEFFERSON
Stone Creek
A
B
C

Three famous hills contain the known supply of Auburn township, viz., the Beller hill, the Shaw hill, and the Lahmer hill. All these are shown in the accompanying map of "Blackband Deposits," section C.

The Beller hill contains an aggregate of perhaps 160 acres of blackband territory. Not less than six separate mining properties are established on it. They are named as follows: Beitzel's, Reif's, and Gribel's, on the north side; Catcott's, Beller's, and Rock Island, on the south. Of these the Beitzel and the Beller workings are nearly exhausted. All the rest hold large bodies of ore.

Both blackband and mountain ore occur here in their characteristic forms. They play fast and loose with the seam, and it is hard to estimate the proportions of each. The aggregate often reaches 8 feet, and sometimes 10 feet. The ore is not worked below 2 feet, as a rule. The ore is mined by system, in drifts, at the present time. About 2 feet of coal is expected with the ore. As much of it as is necessary for calcining the ore is brought out of the mine. A tram road runs from the hill to Blackband Station, on the Wheeling and Lake Erie Railroad. The ore from this region has been taken thus far by the Dover and Massillon furnaces.

The Shaw hill is nearly exhausted, and needs no further mention.

In section 19, there is an area on which blackband ore is believed by some persons to occur, but it has not yet been proved to be present here.

The distance from the Middle Kittanning coal (No. 6) to the blackband in this region is 120 feet, as shown by a single measurement on the Catcott hill.

There are more ore hills in Jefferson township than in any other township of the blackband field. The dividing ridge between Stone Creek and Oldtown Creek, in particular, originally held the largest connected body of ore that we know at this horizon. Erosion has separated it into 8 distinct tracts at the present day. The Upper Freeport coal appears in all of these sections in fair condition. Its quality is better than in the townships already reported. It seldom exceeds 3 feet in thickness, however, and often falls to 2 feet. The ore alternates between blackband and mountain ore, and considerable nodular or kidney ore is found in the overlying shales.

Much of the more promising territory has already been exhausted, but there are still large bodies of ore.

Adam Baker, in lot 30, holds an undeveloped tract in which the

mountain ore, at least, is good. The coal below is also in good condition. David Maughermann, in section 21, has 3½ feet of blackband, and a large amount of kidney ore in the shales above the blackband.

The Harmon and Keffer hill, in section 10, has also 3½ feet of good ore. This is now worked for the Dover Furnace. The underlying coal ranges from 24 to 30 inches in thickness. There is also nodular ore above the blackband.

In section 19, the Kutcher hill is also counted as blackband territory, but is not now worked. In the same section, another deposit has been mainly worked out.

The Rhinehart deposit is limited in area, and is not now worked. The Millhofer hill, in section 16, is mainly exhausted. The Lorenz hill, in lot 36, contains but a small deposit of ore.

On Benjamin Schwab's farm, near Phillipsburg, good ore has been taken by drifting. Quite a large amount has been produced by this bank.

The Meese hill has also a valuable bed of the ore, 3½ to 4 feet in thickness, underlain by 2 to 2½ feet of coal. The seam was mined quite largely by the Glasgow Furnace when it was in operation.

This completes the list of the main banks of the township, so far as they are at present known, but the coal ot this horizon holds a large area in addition to the hills above reported, and it is almost certain that many other bodies of ore will be hereafter found in connection with it. Perhaps the heavier deposits have been mainly brought to light already, but thinner sheets can certainly be worked to profit in connection with the coal that underlies them, if not now, at a future day.

In Salem township six ore hills are known.

The most northerly of them is the Arth hill, in section 3. The ore has not been mined here, but it is known to be present. It is connected with the Rhinehart hill, of Jefferson township, in which the mountain ore predominates. It is therefore probable that this form of the ore will be found in the Arth farm.

The Yackell hill, in section 2, is one of the best-known bodies of ore in the township. It is worked by the Burton-Ridgway Company of Massillon. The ore is genuine blackband throughout, and it reaches a maximum of 9 feet in thickness. The quality is fully approved. All the ore thus far has been taken by stripping, but drifts will soon be required to reach the remainder. A large amount of kidney ore is now

gained by stripping, none of which will be reached in drift mines. A tram-road connects the mine with the railroad, $\frac{1}{2}$ mile distant. The underlying coal is 22 inches thick, and quite sulphurous.

In sections 5 and 6, the Everhart hill has produced quite a large amount of ore for the Glasgow furnace. The haul was a long one, however, and the mine was thus at a great disadvantage. The ore was approved in all respects. The Wiandt hill, in section 14, is nearly exhausted. Its ore was taken by the Glasgow furnace.

The J. S. Dye ore hills were owned by the Glasgow Furnace Company. There are two of them, and, as the map indicates, they are the only deposits of this kind within a radius of several miles. The ore is not at its best in these banks, but it holds well in thickness, ranging from 3 to 11 feet. The underlying coal is 2 feet thick and sulphurous.

This locality has been rendered famous by the most expensive iron-making plant yet made in the State, with one or two exceptions. Scotch capital was brought in for the erection of two large blast-furnaces, which were furnished with the most approved equipment in every respect.

The furnaces were located between two railroads, but at such distances from each as to make a wagon haul impracticable. A branch was finally run from one of the railroads to the furnaces.

The natural water supply of the furnace site was entirely inadequate, and the stock for the furnace was finally pumped from the Tuscarawas River, a mile distant, and 100 feet or so below. The furnace lands held no coal that could by any possibility furnish an iron-making fuel, and they had no limestone of any sort. Two small tracts of blackband were tributary to the furnace, but aside from these, no ore was within reach, except as it was brought by rail or by a long wagon haul. Not only was the supply thus restricted, but the ore of the furnace tract is said to have been inferior in quality to that of many of the banks of the county.

The failure that was foreordained for a furnace without ore, or fuel, or flux, or water, or railroad facilities, was not long in coming, and there is scarcely one stone now left upon another to mark the site where more than a million dollars was so unwisely placed that it could not by any possibility return profit to its investors.

The next deposit of blackband, and the last in the Tuscarawas field, is found in the southeast corner of Oxford township, on the head

waters of Bird's Run. The ore is hauled out to the railroad at Post Boy Station, and is consequently known to many as Post Boy ore. This basin was originally one of the largest of the field, as will be seen by inspection of the map (see page 392). Bird's Run and its minor tributaries have dissected it into ten separate but closely contiguous fragments.

The general thickness of the ore, so far as it has been mined, ranges between 5 and 6 feet. It is not as rich in iron as some other bodies of the blackband, but it is highly approved in use. The Dover Furnace Company owns a large tract of it, and most of the remainder belongs to John Booth.

The interval between the Middle Kittanning coal (No. 6) and the blackband, at this point, is 143 feet, as shown in a single measurement.

The average composition of the ore of the Bird Run field is shown in the following analysis:

Bird Run Blackband—John Booth's Mine. (*Lord.*)

Silica	11.89
Iron sesquioxide	2.00
Iron carbonate	52.61
Alumina	6.04
Lime carbonate	2.57
Magnesia carbonate	2.72
Oxide of manganese	0.60
Sulphur	1.08
Phosphoric acid	0.451
Volatile and combustible matter	18.94
Moisture	1.12
Total	100.02
Metallic iron	26.80
Phosphorus	0.196
Sulphur	1.08

The blackband deposit does not end abruptly with the Tuscarawas county line, but through northern Guernsey county, there is always a probability of more or less carbonate of iron being found above the Upper Freeport coal. These deposits have been examined in a number of instances by explorers for iron ore, but no valuable beds have yet been found.

There are several heavy layers over Steele and Lanfesty's coal on the Ringer farm, near Cassell's Station. Analysis shows the following composition:

IRON SHALE OVER UPPER FREEPORT COAL AT CASSELL'S STATION. (*Lord.*)

Silica	35.34
Protoxide of iron	.77
Sesquioxide of iron	17.15
Metallic iron	12.60
Phosphorus	0.166
Sulphur	13.02

The deposit has no value unless as a possible source of sulphur.

As already stated, the blackband carries enough carbonaceous matter to effect its own calcination when properly ignited. The chief difficulty in calcining it, in fact, arises from excess of fuel. A tough and flexible silicate of iron often forms into an "iron hat" near the upper surface of the kiln, when the heat has been brought to too high a point. This covering is sometimes 12 to 18 inches thick, and very hard to dislodge or break through, and an extensive crust of it detracts very much from the value of a kiln.

Kilns for calcining the blackband are generally made 120x30x7 feet. The height of the kiln must be proportioned to the amount of carbonaceous matter in the ore. Too high a heat, together with an insufficient supply of air, leads to the formation of the "iron hat" already noticed. Kilns require 3 or 4 months' time for burning, and after being once ignited, demand but little care. Each kiln yields about 600 tons of calcined ore, which overruns 50 per cent. in metallic iron.

The price for the raw ore in the hill usually ranges between 20 and 35 cents per ton.

This completes the account of the Tuscarawas blackband field. No explorations of new territory have been attempted, but the sole aim of the present survey has been to indicate the present state of development of the field. The maps of the leading areas appear here for the first time, as does also the general blackband area of the county (page 257). Doubtless, many additions will be made to the tracts already known, but it is probable that the larger bodies have been already struck, as a good deal of intelligent and expensive proving has been carried on within the last 10 or 15 years throughout the available territory.

Among those most prominent in these explorations, Mr. A. Wilhelmi, of Dover, the Dover Furnace Company, and the Ridgway-Burton Company, of Massillon, deserve special mention.

b. Kidney Ores.

The kidney and block ores of the counties now under consideration remain to be briefly noticed. They are limited to the two counties, Stark and Tuscarawas, and almost exclusively to the latter.

The kidney ores will be first treated. Mention has been already made of the occurrence of many nodules and kidneys in the shales above the blackband, which are often mined with the latter. These require no further notice, and only one horizon needs to be named as a further source of kidney ore in this district. The Kittanning shales, or the 20 to 40 feet of clay and shale that separate the Lower and Middle Kittanning coals, have already been shown to be a chief repository of kidney ore in the territory to the southeast of this. The "placer" mines of the Little Beaver Valley have obtained most of their ore from this source, as has been stated. But the same stratum proves even richer in ore as it is followed to the westward. At least the kidneys are gathered here into a distinct seam that justifies mining on a small scale.

The ore is known in Tuscarawas county as shell ore. Its place is immediately under the thin seam of coal that comes into the section locally, midway of the Kittanning shales. This leaves the ore about 20 feet above the Lower Kittanning coal (No. 5), and about the same distance below the upper seam (No. 6). The ore occupies 4 or 5 feet of white and purplish clay, and will aggregate 12 to 18 inches in thickness. In quality it is excellent, only the mellow and aerated kidneys having been reached thus far in the simple style of mining followed. All the ore that has yet been dug, has come from the shallow benches cut down around the edges of the hills. It is only in the neighborhood of the furnaces, and along the lines of the railroads, that mining has been carried even as far as this. It is not known that a single drift has ever been carried under the hills in pursuit of the kidney ore.

This horizon can scarcely maintain itself in present competition with the blackband hills where nothing less than 2 feet of ore is counted mineable, and where the average of entire acres will exceed 5 feet, but it is well to remember that the kidney ore is here, and that its aggregate

in the county vastly exceeds the more conspicuous source which the isolated caps of 40 or 50 separate hills, scattered through 100 or more square miles of territory, contain. Small supplies can be continued to local furnaces for a long while to come.

c. *Block Ores.*

The block ores of the district can be dismissed with even briefer mention. There are three sources of them—the two Mercer limestones and the Putnam Hill limestone. A fourth source must be added for a few localities in Tuscarawas county, viz., the shales immediately above the Lower Kittanning coal (Coal No. 5). In the vicinity of Dover, this ore has been taken in considerable amount in connection with the coal which it overlies but a single foot. It is 3 inches thick, is blue and close grained, but is well esteemed. Of course, it would not be mined by and for itself. It is called the blue block ore.

The same statements apply to the other block ores. They have been taken out in but very small quantity, except as an incidental product in the mining of the limestones for furnace flux. As the limestones are reached altogether by benching or stripping, nothing but weathered ore is ever met, and this fact helps to give the block ores an excellent name where they are used.

No iron ores are mined in Coshocton or Holmes counties, though several of the seams already named have a fair development here. If a furnace had been established at any convenient point, there is no reason to doubt that the usual and persistent horizons of both block and kidney ores would have been found present in more or less of the territory.

Blackband of Holmes County.

No better place will be found for a brief account of a stratum included in this general district that has provoked a good deal of discussion within the last few years. It was first described by the late Professor E. B. Andrews in a report of an examination of the then projected line of the Cleveland, Canton, Coshocton and Straitsville Railway Company, now the Coshocton branch of the Connotton Valley Railway.

The stratum in question is a so-called blackband deposit, immediately over the Lower Kittanning coal (No. 5), occurring at a few points in German township, in Holmes county, and perhaps also in contiguous territory. Professor Andrews describes it as follows:

"Quite to my surprise, I found very large deposits of blackband over coal No. 5. At one point, where coals No. 6 and No. 5 are both well exposed, the shales between the two seams, here 18 to 20 feet apart, are very thickly studded with large nodular masses of ore, and hundreds of tons were exposed in the immediate neighborhood. But a half mile away, we find 10 feet or more of the black bituminous shale over No. 5 so largely charged with iron in even diffusion as to constitute a blackband ore. . . North about a mile and a half is an extensive and elevated ridge where the exposed blackband over No. 5 is 10 feet thick. It is of equal thickness at another exposure in the same ridge about a mile further north. About 2½ miles in a northwest direction from the last-mentioned point is another exposure where the blackband ore is equally thick, 7 feet 6 inches being in sight, with probably considerably more below."

Analyses were made of two of these deposits, one of the analyses being supposed to cover 7 feet 6 inches of ore, and the other 5 feet 6 inches. The samples yielded of metallic iron, 27.32 and 22.62 per cent., respectively. These figures place the ores, as Professor Andrews justly remarked, on a level with the Tuscarawas blackband.

The table of analyses is given herewith from Professor Andrews's report:

"I give, in the following table, the results of the analyses of these ores over coal No. 5, and also of the blackband over No. 7, from Tuscarawas county, copied from the Ohio Geological Reports. All the analyses were by Prof. Wormley.

The analyses show that the blackband ores over coal No. 5 are of excellent quality, and compare favorably with the famous blackband ores over coal No. 7, in Tuscarawas county."

No. 1. Blackband over coal No. 5.

No. 2. Blackband over coal No. 5.

Nos. 3, 4, 5 and 6, are Tuscarawas blackbands over No. 7 coal.

Analyses of Blackband Ores.

	1.	2.	3.	4.	5.	6.
Silicic acid	25.52	24.16	26.22	30.32	21.84	27.20
Volatile matter	13.30	20.06	21.10	11.70	26.28	18.80
Iron carbonate	45.86	33.60	34.69	39.31	36.64	38.51
Iron sesquioxide	7.40	9.14	10.42	9.50	9.03	6.25
Alumina	0.50	5.75	0.70	....	1.00	1.00
Manganese	2.10	1.85	1.70	1.30	0.30	2.35
Lime carbonate	1.50	0.95	2.00	2.86	2.00	2.72
Magnesia carbonate	3.26	4.20	1.84	2.50	1.96	2.49
Sulphur	0.17	0.30	0.11	0.31	0.13	0.21
Phosphoric acid	0.096	0.032	....	....	tr.	0.63
Lime phosphate	....	....	1.07	1.20	....	....
	99.706	100.042	99.85	99.09	99.18	100.16
Metallic iron	27.32	22.62	24.06	25.63	24.00	22.96
Phosphorus	0.043	0.018	0.27	0.30	tr.	0.28
Iron in calcined ore	43.94	35.08	37.69	35.91	41.27	35.72

Professor A. A. Wright, of Oberlin College, who made the review of the economic geology of Holmes county for the present report was instructed to give special attention to these deposits. He did so, visiting all the accessible exposures. He sent in for analysis, samples of the 7 to 8 feet of ore on Christian Fisher's farm, German township, perhaps the best-known and most trusted of these deposits. The results are given below (No. 1). The average of the seam was taken.

Afterwards I visited the Fisher bank in person, and selected two sets of samples, the first to show the average of the seam, and the second to show the composition of the most promising layers. These are given below in Nos. 2 and 3. In No. 4 the composition of the nodular ore from the same horizon is shown. The samples were taken from a heavy deposit in the Rowville cut of the Connotton Valley Railway.

The ferriferous character of the horizon has been fully established by 100 miles of outcrop in the eastern counties. It is the same stratum, viz., the Kittanning shales, it will be remembered, that bears the shell ore and the blue block ore of Tuscarawas county, and the kidney ore of Columbiana county. It is therefore no surprise to find iron accumulated in force at this level in Holmes county, but blackband has not been heretofore reported from the Lower Kittanning seam. The Fisher bank, which is represented in the analyses given below, Nos. 1, 2 and 3,

deserves the name of blackband ore. It has too much carbonate of iron to allow it to be called a bituminous shale. The results obtained by Professor Andrews would make the deposit a very valuable bed of ore. The results obtained by the Survey do not indicate any real economic value under present conditions of iron making. The disparity in the two sets of analyses, it is hard to explain. Professor Andrews's work is entitled to respect, and certainly the Survey has not spared trouble to ascertain the facts.

	1.	2.	3.	4.
Silica	37.52	34.28	28.82	8.67
Iron protoxide	13.75	15.29	19.85	43.11
Iron sesquioxide	1.57	4.64	5.43	0.42
Alumina	....	....	13.31	4.47
Manganese oxide	....	....	0.04	2.07
Lime	....	....	2.95	5.15
Magnesia	....	....	0.94	2.09
Carbonic acid	....	....	15.46	32.74
Phosphoric acid	....	....	0.275	1.176
Sulphur	....	....	1.810	0.178
Water and organic matter	....	....	8.95	0.25
Moisture	....	....	0.58	0.12
	....	....	98.41	100.44
Metallic iron	11.80	15.15	19.25	33.85
Phosphorus	0.160	0.071	0.120	0.513
Sulphur	0.699	.255	1.810	0.118

The discussion can be summed up in few words. If there is any considerable body of ore, 3 feet in thickness, let alone the 6 to 10 feet reported, that will yield before calcination from 22 to 27 per cent. of iron, as shown in the above quoted tables, the work of iron manufacture may be begun immediately, and its success can be guaranteed, so far as ore is concerned. No such body of ore was found by the Survey. On the other hand, if the Fisher bank fairly represents the blackband of this district, then iron-making can not be successfully begun here in our day.

4. Iron Ores of Muskingum, Licking, and Northern Perry Counties.

This district includes the ores that are tributary to the Zanesville furnace, the production, of course, being limited to a certain extent by the lines of transportation. Three townships of Muskingum, viz., Jack-

son, Licking and Hopewell, four of northern Perry, viz., Jackson, Pike, Reading, and Clayton, together with Perry and Hanover, of Licking county, have furnished almost all of the ore of this district up to the present time. The three block ores of the Mercer limestones and the Putnam Hill limestones, respectively, are the main sources. A little of the Ferriferous limestone ore, here known as the Baird ore, has been added to the production from one or two townships.

The Lower Mercer ore is much the most important of the series. In Muskingum county it exceeds a foot in thickness for considerable areas. It is mined only on its western outcrops, or at least where it lies high in the hills. The ore is consequently at its best, and no complaint is made as to quality. It has been mined exclusively by stripping, and it is scarcely probable that it will be sought in any other way. The limestone is not always present, and where it disappears the ore often seems to be the gainer.

The same statements apply to Licking county, the present ore production of which is, however, insignificant.

The other block ores appear in their proper horizons, and are both worked to some extent, but they are less valuable than the Lower Mercer.

Frazeysburg, Claypool's Station and Nashport Road are the chief shipping points of the ore.

A sample of the Upper Mercer block ore of this district from the farm of W. France, Newton township, Muskingum county, was analyzed, with the results given below. The ore was 12 inches thick, and seemed persistent.

Silica	5.38
Iron protoxide	42.53
Iron sesquioxide	7.85
Alumina	3.61
Manganese oxide	1.75
Lime	3.57
Magnesia	2.45
Carbonic acid	31.53
Phosphoric acid	0.431
Sulphur	0.241
Water and organic matter	0.53
Moisture	0.38
	100.25
Metallic iron	38.60
Phosphorus	0.188
Sulphur	0.241

This is in all respects an excellent ore. With the volume reported, it must repay working, at least upon outcrops.

A different condition of things is to be reported in northern Perry county. A block ore appears there, 15 feet *below* the Lower Mercer limestone, and this proves to be the chief ore of the horizon for a large territory to the southwestward. It is from 4 to 8 inches in thickness, and is persistent and steady. It has been largely mined at Junction City, Jackson township, and it is consequently known as the Junction City ore. It agrees altogether in character with the regular ore of this horizon, yielding iron of great strength and excellence. It is probable that a duplication of the limestone sometimes occurs at the same level, but in many cases the same general conditions of iron formation are shown in this ore that mark the main Lower Mercer block ore. The suggestion that this lower ore occurs in the place of the Lower Mercer coal can also be considered.

The hills of Jackson township have been disfigured by extensive ore benches, along the railroad lines, in years past, but for several years no ore has been produced here.

As has been already stated, a small amount of Baird ore, the limestone ore of Southern Ohio, has been mined in Perry county. The seam is light and uncertain, and prices for ore must range very high to justify working it in the scattered hill tops. The ore, though thin, is thoroughly characteristic in itself and in its associations. It is capped with the whitest clays of the series, and flint and limestone are frequently found supporting it. It occurs mainly in the form already described, of small shot-like concretions in a silicious clay. It is not an important element of mineral wealth in this region.

There is a large area in the district now under consideration, which is properly situated to hold the ores already described, but in which no inducement to open or mine them has yet been offered. The surface indications in these townships are often excellent. In Madison, Clayton and Harrison, of Perry county, especially, there is every reason to expect full horizons of the block ores. The natural outcrop is in some cases unusually promising.

5. Iron Ores of Southern Perry and Hocking Counties.

THE HOCKING VALLEY.

The ores of the region now to be considered are of considerably greater importance than those described in the last section. They came from more and better horizons, and they have been worked in a much larger way. The principal addition in the matter of horizons of ore is the reappearance of the blackband in strong force and good condition in the central part of Perry county. The Ferriferous limestone (Baird ore) is also largely worked in Hocking county. Only one of the block ores is worked to any great extent, and this comes from the level of the Junction City ore, 15 feet below the Lower Mercer limestone.

The geological section including these ores is repeated here to make the statements that follow more easily intelligible. One ore from the Barren Measures will need to be considered here, as all the developments of it have associated it with the main seams of the Lower Measures. The order is as follows:

Dugway ore.
Mahoning sandstone—thin.
Upper Freeport coal (Coal No. 7), carrying blackband in places.
40 to 50 ft. Upper Freeport clay and Buchtel ore.
Upper Freeport limestone and Straitsville ore.
Lower Freeport coal—Coal Nos. 6*a* and 6*b*.
30 to 50 ft. Lower Freeport sandstone—often shale.
Middle Kittanning coal—Coal No. 6.
20 to 40 ft. Kittanning shales, holding Snow Fork kidney.
Lower Kittanning coal—Coal No. 5.
10 to 20 ft. Baird ore (Limestone ore of Hanging Rock).
Ferriferous limestone.
60 to 70 ft. Limestone kidney or block—Putnam Hill horizon.
Upper Mercer limestone and ore—unsteady.
Upper Mercer coal—thin.
20 to 30 ft. Lower Mercer limestone and ores.
Lower Mercer coal.
40 ft. (?)
Wellston or Quakertown coal?
60 ft. (?)
Sharon coal horizon?
Maxville limestone and block ore—Sub-carboniferous.

a. Blackband and Clay-band Ores.

The last point at which we found ore to be taken from the Upper Freeport or main blackband horizon in coming south and west is in Oxford township, Tuscarawas county. The counties of Coshocton and Muskingum have been passed without the report of a single deposit of this character. The ore is not likely to be found in central Muskingum county, as we know from the fact that the coal is already mined extensively through a number of townships here, and the horizon has thus been fully disclosed. If the ore had been present, it would certainly have been brought to light. It has been already shown that in the occurrence of the ore thus far, it has occupied the exterior margin of its field, the mineable coal being found farther within the basin. In other words, the landward side of the coal swamp received the supply of iron, probably in the waters of the drainage streams that found their way to it. The Stark and Carroll county deposits, for example, are found on the very westernmost outcrop of the Upper Freeport level, while the Dell Roy coal field lies a dozen miles or more from this outer margin. In the same way, the Tuscarawas ore-hills mark the outermost exhibition of the Upper Freeport horizon in that county. The Cambridge coal, on the other hand, lies 20 miles within this boundary. In parts of Muskingum county, as just stated, the coal is found of good thickness on the western outcrop of the seam, without the ore, but in central Perry county the conditions found in Carroll and Tuscarawas counties are repeated. Valuable beds of stratified ore mark the northwestern outcrop of the Upper Freeport seam, while a still more valuable seam of coal is found as the horizon dips down toward its final cover to the southward.

The blackband ore of this region was first discovered in the neighborhood of Shawnee. The hill on which it was found was named Iron Point, and the ore has been generally known as the Iron Point ore, but sometimes as the Shawnee ore. It is confined to section 10, Pike township.

The ore lies about 100 feet above the Middle Kittanning coal (No. 6), which is here the basis of all sections. The range of intervals is, however, considerable, the distance being sometimes reduced to 90 feet, and occasionally rising to 120 feet. The level of the ore in a mine that covers even less than an acre will frequently be found to have a

range of 20 feet. These facts are entirely in keeping with the general character of the horizon.

In composition the ore is not in most cases a true blackband, but much of it would rather come under that division of the stratified ores called clay-bands. Thin streaks of coaly matter are distributed between the drab-colored layers of carbonate of iron. Below it there is often found, as in the other fields, a foot or two of coal, generally poor in quality, and not enough can be depended on to effect the calcination of the ore.

The blackband in the immediate vicinity of Shawnee is supposed to have occupied about 20 acres, but it is now practically exhausted, only a few small areas being left of the original deposits. Four furnace stacks were built, upon the discovery of the ore, and they have made, in their short career, quick work with what has been discovered up to this date. One furnace might have found a profitable life in the field, with the blackband for its main reliance, but four necessarily brought about a rapid exhaustion of the limited supply.

The ore seldom rises above 3 feet in working height, and the average of the worked areas will not probably exceed 2 feet. It was largely mined by "stripping" or "tailing" at first, but that stage was soon passed, and almost all is taken from regularly opened drifts at the present time. The calcined ore yields more than 50 per cent. of metallic iron.

In section 14, of Pike township, about equally distant from New Lexington and Moxahala, the valuable deposit known as the "Hone ore" was found. The bank covered less than 2 acres, and reached a maximum thickness of 8 feet. It has been entirely mined out. It was a distinctly stratified ore, but contained no carbonaceous seams. It was quite light in color when under cover. The outcrop was a rich and mellow limonite. A question has been raised as to the true geological place of this ore, but there does not seem to be sufficient reason for rejecting the general conclusion that it lies at the blackband horizon.

No such question exists in regard to the "Whitlock ore" which is found in section 14, Bearfield township. This is certainly at the Upper Freeport horizon, and, moreover, it is a true blackband. A long and valuable section was measured in this vicinity, including the Whitlock bank. It is as follows:

Ames limestone.
Interval—not measured.
Cambridge limestone.
Interval .... 50 feet.
Brush Creek coal—No. 7*a*,
Interval .... 45 feet.
Whitlock ore—Upper Freeport coal—No. 7.
Interval .... 61 feet.
Nodular ore and fire-clay—Lower Freeport horizon?
Interval .... 51 feet.
Middle Kittanning coal—No. 6.
From lowest coal to ore, 117 feet; from same to Cambridge limestone, 212 feet.

So far as worked, the seam has ranged between $1\frac{1}{2}$ and 4 feet in thickness. It carries enough coal and carbonaceous matter to effect its calcination. It is under much heavier cover than most of the ore bodies of this horizon. In fact, not another occurrence of genuine blackband has been noted in the State directly beneath the Ames limestone. The area already mined will not exceed an acre, but the hills come down so abruptly that the possibilities of tailing or stripping the ore have already been exhausted. Drifts have been pushed under the hill, but they are not now open. According to what seems reliable testimony, the ore was left at full thickness at the head of the drifts. If this be true, there is still a considerable amount to be looked for in this region. The horizon can be marked through a large territory. All the ore that was mined here, was taken to Moxahala Furnace. The raw ore contains 36 per cent. of iron.

There is another important field near Bristol, in the southwestern corner of Pike township. Two bodies of the ore have been found and worked in sections 29 and 32, respectively. The former is known as the Clark ore from the name of the farm on which it occurs; the latter is, for a like reason, called the Bowman ore. Both have been worked quite largely, the former for Moxahala Furnace, and the latter for the Shawnee furnaces. The average thickness of the Clark ore is less than 15 inches. The Bowman ore covered originally about 22 acres, and probably two thirds of it have been mined out. It occurs in two benches, separated by about 15 inches of shale. The upper ore bench is 6 inches thick; the lower ranges between 12 and 15 inches. The ore is mainly mined by stripping. A tram-way conveys it from the mine to the railroad at McCuneville. These deposits are not equal in value to the Iron Point beds. They fall below in thickness, and perhaps also in

quality, but they have already yielded many thousand tons of iron, and the supply is not exhausted.

To the south of Moxahala, several large deposits of rough ore occur at the same general level, but experience does not warrant us in assigning to them any real value as sources of iron. One of them is so high in phosphorus that it would serve a better purpose as a fertilizer than as an iron ore.

In section 2, Ward township, Hocking county, on the Helen Furnace lands, a blackband ore has been opened and worked to the extent, at least, of several thousand tons. It lies 93 feet above the main coal (Middle Kittanning or No. 6). It carries a foot or two of coal above it (Upper Freeport or No. 7), and below it there is also a sulphurous, carbonaceous deposit that verges toward coal. The Lower Freeport coal also appears in the section. The ore ranges from 6 to 15 inches in thickness. It lies under comparatively light cover. When calcined it yields fully 50 per cent. of iron. It has been mined by drifts, and shows itself a persistent deposit, so far as it has been followed. It appears to hold a considerable area, being found in several tracts that are separated by valleys. It did not work as kindly in the furnace as could be desired, and since it cost as much, or nearly as much, as the Baird ore that the other furnaces of the valley were handling, it was found necessary to abandon its use, at least for a time.

This completes the enumeration of the blackband deposits that are now worked or that have been worked in the Hocking Valley. The discoveries of these several basins have all been made by practical men, coal miners or ore diggers, and the first found were a source of surprise to the geologists who were best acquainted with the field. So long an interval exists between the Tuscarawas blackband field and Perry county that there seemed good reason for believing that the iron-making stage of the Upper Freeport coal horizon had already been left behind.

This new blackband field is by no means equal in value to the older one, but it made a notable addition to the iron ores of the valley. In the light of what is now known, it is clear that it has not been turned to the best account in an economic point of view.

Two other ores of the Upper Freeport horizon have been worked during the last few years in the Hocking Valley, though neither of them is the basis of present operations. They are known as the Buchtel and Straitsville ores, respectively. The former belongs at the horizon

of the Upper Freeport clay, underlying the coal of the seam, and, consequently, the blackband by 5 to 15 feet. The Straitsville ore is borne by or replaces the Upper Freeport limestone, which is here separated from the coal by an interval of 20 to 30 feet. The Straitsville ore is thus 60 to 70 feet above the main coal (No. 6), and the Buchtel ore, 80 to 90 feet above the same base. The usual interval between the two ore horizons is 15 feet.

Both of these ores are local in their occurrence, and they are not by any means persistent beds. The Buchtel ore has by far its best development in the vicinity of Buchtel Furnace, where also it has been largely worked, and the location of which was fixed in part by the presence of these deposits; the Straitsville ore has been mined in the large way at but a few points, viz., in the hills adjacent to New Straitsville, from which several thousand tons were taken out a few years since, and from the vicinity of Moxahala, where many unsuccessful efforts have been made to find in it a safe basis for iron manufacture. It is known here as the Sour apple ore, or as nodular ore.

The Buchtel ore is a lean carbonate of iron, always calcareous, and often passing by easy gradations into an impure limestone. The nodules or bowlders that compose it are of large size, and are very hard and heavy. They are imbedded in clay, and are light gray in color, sometimes inclining to blue. The thickness of the seam at its best is between 5 and 6 feet, and there are considerable areas where it exceeds two feet in thickness. The upper portion, where the seam is thickest, generally consists of a separate layer of nodules, more calcareous than the main seam, and called, distinctively, bowlder ore. The outcrop ore is rough and unpromising for the most part, though an occasional mass of fair quality is found. Analysis of seven samples, selected from the stock pile of calcined ore at Akron Furnace, when the seam was first worked, showed an average of a little less than 21 per cent. of metallic iron (*Howard*). The bowlder ore was mined with the rest of the seam at this time. When this is left out, the percentage runs higher. The best of the calcined ore is said to yield 33 per cent. in the furnace. There is a considerable amount of lime in it, but the proportions are entirely uncertain, and it can never be safely used for flux. There is no way of knowing what proportions of iron and lime go into the furnace top where the products of this seam are used.

The same seam has been mined on a large scale at the new furnaces

at Floodwood. The ore taken out was mainly outcrop ore, and it thus makes the best possible showing for the seam. Of the many thousand tons mined here, it seems quite doubtful whether one pound will ever be charged into a furnace stack. No experienced iron-master would consent to run such a stock pile through a furnace.

This stratum, though massive and conspicuous, is not, therefore, considered as adding to the resources of the valley in iron manufacture.

The same conclusion is reached in regard to the Straitsville ore. It is exceedingly treacherous as a geological element, the ore playing fast and loose with the limestone to which it belongs, and always making a better appearance on the outcrop than under cover. It is also very unsteady in composition. Moxahala furnace was built to run upon these nodular ores which make a conspicuous feature in the geological sections of that part of the county. Under the management of J. G. Chamberlain, Esq., an experienced iron-master, investigation was made of every deposit in the vicinity that held out any promise. Not one was found that would repay working. Zanesville furnace also experimented with this ore with similar results. There is not a point in the Hocking Valley where this horizon is yielding any ore at the present time, though a great deal of outcrop nodular ore could be supplied at low rates.

With such conditions applying to these seams, it does not seem necessary to give further details in regard to their development or distribution.

A line of facts, similar to the foregoing in many respects, is found in what is called the Dugway ore. This is a deposit of the same general character as the Buchtel ore, but lying above the lower stratum of the Mahoning sandstone. The ore probably occurs at or a little below the horizon of the Brush Creek limestone. It lies from 15 to 30 feet above the Upper Freeport coal (No. 7), and about the same distance below the Brush Creek coal (No. 7*a*).

It occurs in massive blocks or bowlders that lie in a red and white clay. The bowlders will often make a thickness of 3 or 4 feet, in an aggregate of 6 feet of outcrop. The horizon is quite steady, being shown in almost every section where it is due, especially along the Sunday Creek Valley. An analysis of a selected sample of the weathered ore from the farm of Joseph W. Jones, on Mud Fork, near the Blondin well, gives the following results:

Analysis of Dugway Ore, Mud Fork, Trimble Township. (*Lord.*)

Silica	11.97
Iron protoxide	29.04
Iron sesquioxide	14.43
Alumina	6.29
Manganese oxide	0.83
Lime	6.10
Magnesia	2.83
Carbonic acid	25.68
Phosphoric acid	0.828
Sulphur	0.024
Water and organic matter	2.41
Moisture	0.41
	100.84
Metallic iron	32.70
Phosphorus	0.361
Sulphur	0.024

Iron could be made from an ore that would maintain this character and composition, but experience has shown a rapid reduction in the percentage of iron as soon as the outcrop is left. A few attempts have been made to mine and work the ore. At Corning several hundred tons were taken out of the seam, which is in full development and easily reached, but the use of the sample that was mined created no demand for more. The ore appears somewhat better than the two deposits last described, but it may be necessary to relegate it to the same quiescent state under present conditions of iron-making.

There remain to be considered two other classes of ores that are mined in this portion of the field, viz., block and limestone ores.

There is one persistent and widely worked block ore that has been mined in every township in which its horizon is struck within these two counties. It is the ore already described as the Junction City block ore. It is also known as widely as the Union Furnace block ore. It lies about 15 feet below the Lower Mercer limestone. It has been extensively worked in Jackson township, Perry county, for Zanesville Furnace; and also to some extent in Monday Creek township, for Baird Furnace. In Falls, Green, Starr and Washington townships, of Hocking county, it has furnished a large supply to at least four furnaces, viz., Union, Logan, Baird's, and Craft's. The largest production of this county has been in Green and Starr townships. For a number of years

Union Furnace obtained its chief supply from this seam in Starr township, and Logan Furnace drew quite largely for its ore from this horizon in Falls township. The block ore of Green township makes a small contribution to Craft's Furnace.

The ore ranges, as usual, from 4 to 8 inches in thickness, averaging about 5 or 6 inches. All that has been mined is outcrop ore, taken from stripping benches. This grade yields somewhat more than 40 per cent. of iron, the quality of which is excellent. The ore is low in phosphorus, and its sulphur can be easily controlled. It has a tendency in some places to run into flint. The future production must be limited by the extent of available outcrop, as the thinness of the seam forbids the following it under cover. There is still a large amount of territory that can be reached by existing lines of communication.

There are several other block ores in the field, but none of them has been worked to any notable extent.

The Baird ore of this district is the "Limestone ore" of the Hanging Rock field. It has already been described as occurring to a small extent in Reading and Clayton townships, of northern Perry county. It becomes an element of real value in Pike, Jackson and Monday Creek townships, of southern Perry, and also in Gore, Green and Starr townships, of Hocking county. There are also valuable bodies of it in the highest hills of Falls and Washington townships, but the area here is quite small.

Throughout the territory now described, it has been worked on a large scale for many years. Not only the furnaces already named, but three others in addition, viz., the Bessie, the Thomas Iron Company's and Winona furnaces, have all obtained large amounts of ore from this thoroughly known and thoroughly approved seam. It retains all the characteristics that have given to it its excellent reputation in Southern Ohio. It occurs in the same form, and in the same stratigraphical associations as there, but its thickness is a little less than in Lawrence and Jackson counties. It averages 8 inches here for the whole territory against 10 inches in the southern parts of the field. Of course, it often rises to 12 inches, and sometimes to double this measure, but this extra volume has generally to be paid for by corresponding decrease in the surrounding territory. It is separated from the Lower Kittanning coal by a very white seam of clay (the Kittanning clay), which ranges be-

tween 10 and 20 feet in thickness. The Ferriferous limestone is fully developed in some parts of the field immediately below it, as at Ilesboro, Washington township. Northward it is found more or less in all large workings, but it is thin and inconspicuous, seldom showing in outcrop, and is often absent from the section altogether. It is often replaced or represented by a white flint, as in the southern counties. The ore has been mined by stripping only, and the benches of white clay, many miles in length, that mark the centers of production, are among the most noticeable features of the country. The outcrop ore is naturally most valued and sought for, but the seam appears to hold quite steady under heavy cover. Its place in the series ranges from 30 to 50 feet below the Nelsonville coal, which is the standard element in all sections in this field. The usual interval between the coal and ore is 40 feet. Guided by measurements alone, explorations have revealed the presence of the ore in parts of the field where it would scarcely be looked for. Mr. W. B. Brooks proved the existence of a fine and characteristic stratum of it under his coal at Nelsonville. It is also found on the Hayden tract, under quite heavy cover. A thin development of it extends through the hills to the Monday Creek Valley, where it has been opened on the Cawthorn farm. It seems to have reached its natural limit at this point. It has been mined as far east as Shawnee, in Salt Lick township, where it lies just above drainage.

The ore is almost entirely of the oölitic variety throughout the Hocking Valley, and, though not over rich in iron, and quite high in silica, it is so free from sulphur and phosphorus, and is otherwise so constituted, that it yields an iron of great tenacity and consequent value. The mill iron manufactured from it is noted for its strength, and finds market even where very rigorous demands as to this quality are made.

No mention has been made of kidney ores in the field now under consideration. There are none that contribute to the iron manufacture of the district at the present time. Only one persistent horizon is to be found here. The Kittanning shales, occupying in whole or in part the interval between the Kittanning coals (Nos. 5 and 6), have been found to be ferriferous around the whole margin of the field thus far. They offer no exception here. A kidney ore of unusual and marked characteristics occurs everywhere in the shales below the Nelsonville coal. The kidneys sometimes approach within 2 or 3 feet of the coal,

and sometimes they recede 12 or 15 feet from it. They are not gathered into a seam, but are scattered irregularly through the clay and shale. They consist of a very fine-grained and consequently heavy blue carbonate. They are generally more or less symmetrical in shape, inclining to a discoidal form. A marked peculiarity of the ore is that it contains throughout its substance fragments of fern leaves, and other carboniferous plants in exquisite preservation. When freshly broken, the most delicate venation of the leaves can be observed. Insect remains have not been reported in these kidneys, but their occurrence would be no surprise to those that have studied the deposit, as there are many points of resemblance between these nodules and other Carboniferous concretions which have yielded such remains. The ore maintains this peculiar fossiliferous character, in places, as far south as Willard, Kentucky.

The ore is rich in iron, and the quality is not in any respect unfavorable, so far as analysis has shown, but the fact that it lies scattered to such a degree, forbids the mining of it. Tradition records, however, that it was the first ore ever turned to account for iron making from the Hocking Valley. A boat load was taken to the Mary Ann furnace, near Granville, in the early days of the Ohio canal. On both sides of the Ohio Valley, as will be presently shown, this ore has been and still is quite extensively worked.

From this review it will be seen that all of the ore now mined in the Hocking Valley comes from the three well-marked horizons named below:

Blackband or Iron Point ore, accompanying Upper Freeport coal.
Limestone or Baird ore, borne by Ferriferous limestone.
Block ore, below Lower Mercer limestone.

Several other horizons have been named at which ores of various grades and character appear. Some of these ores have been experimentally worked, but none of them have been found to justify larger and continuous operations.

Of these three ores the most accessible portions have already been largely taken. The outcrop furnishes not only the cheapest, but on every account the best ore of the seam. This outcrop ore has been followed or "tailed" into the hills, at least as far as the empirical mining rule, "a foot of stripping for an inch of ore," would require. This is certainly true for most of the lands naturally tributary to the

older furnaces, viz., Baird's, Gore, and Bessie. There are still large bodies of ore from these several horizons that have been described, under deep cover in the hills, but present conditions of iron-making forbid the mining of these shallow seams, except by shallow stripping. To work them in drifts adds not less than 50 per cent. to the cost of production, and the product cannot bear the tax. It does not therefore seem possible that the native ores of the valley can ever again hold as prominent a place in the iron-making of the valley as they have thus far held through its short history. Every year brings Lake Superior and other great sources of iron practically nearer to this field, and while these native ores may long be sought in small amounts to impart certain particular qualities that are desired in the iron to be produced, the furnaces will soon come to place their main dependence on high grade foreign ores, relying upon the valley for the purest and best iron-making coal of the State.

6. Iron Ores of the Hanging Rock District, including the Counties of Vinton, Jackson, Gallia, Scioto and Lawrence.

The district which is now to be considered is by far the most important of the Ohio field in respect to the production of iron ore. Blast furnaces were established here more than 60 years ago, the entire ore supply of which was derived from the adjacent furnace land. Not only have these first established furnaces been maintained in uninterrupted activity for the most part, but many new ones have been built from time to time, and the iron manufacturing interest has come to be recognized as, next to agriculture, the most important of the district. All of the earlier furnaces, and many of the later ones, are charcoal furnaces, the organization of which is as follows:

There is attached to each furnace a large body of land, often consisting of several thousand acres, from which the whole furnace stock, ore, flux and fuel, must, as a rule, be derived. Certain main horizons furnish the chief supply of ore, but every addition to this supply is welcomed. No indication or "blossom" is neglected or left unproved. While this state of things is true at all of the furnaces, there is special stress laid upon the discovery of ore seams at such of them as are situated outside of the main ore belts. The westernmost furnaces, as a rule, have the most precarious supply, and it is upon the western margin

of the furnace district that we find the largest number of separate ore seams counted, many of which have been but little worked, and which would never have been worked at all, except for the urgent local demand.

As a result of all this sharpened inspection, the furnace managers have been led to recognize several locally important seams of ore in addition to the well-known and persistent horizons that have been followed thus far around the margin of the coal field.

Of the persistent horizons, as has been often repeated in the preceding pages, by far the most valuable element is the Ferriferous limestone. It has been found coming clearly into the sections of southern Perry and Hocking counties, and from this region it extends to the southward with almost unbroken continuity. Its ore rates as high in value as in persistency.

The Mercer horizon is also exceedingly serviceable. The lower limestone of this group can be followed without real interruption from the Pennsylvania line to the central part of Jackson county. From that point to the Ohio Valley it is not steady, but it is found often enough to establish the sections. The ore that goes with it maintains its place, even when the limestone temporarily disappears.

The coal seams are also valuable guides in following the series from point to point, and when limestone, ore and coal are all brought into requisition, a very clear and symmetrical order comes to light.

The ores of the Hanging Rock district can be divided on stratigraphical grounds into three quite natural groups. It will be more convenient to treat of them in these divisions, though the classification already proposed will not be lost sight of. The divisions are as follows:

1. The lowest division extends from the Sub-carboniferous limestone to the Mercer group, including both. The most characteristic and valuable elements of this division are block ores. In fact, all of the block ores of the entire series are embraced within these limits. Three persistent and six more or less important ores must be referred to this group. This division embraces 225 to 250 feet of strata.

2. The second division covers the famous ore of the Ferriferous limestone horizon, which is the central feature of the whole district, and it may also be made to include the two weaker ores that lie next below the limestone, and which are often known as limestone kidneys.

At most, there are but three ores in this division. The section measures about 100 feet.

3. To the third division, which in its leading elements embraces about 150 feet, may be assigned all the ores that are worked at horizons higher than the Ferriferous limestone. According to the limits thus far followed, the upper boundary of this section should be the Mahoning sandstone, but convenience will be subserved in the present instance by transcending this limit, and considering here all of the remaining ores of the region. This section is mainly composed of kidney ores, of which there are two and sometimes three fairly regular horizons, but the banded ores of the Upper Freeport horizon must also be included with this group. There is not a marked development of the latter type of ores in the Hanging Rock district, but on one furnace tract some mining is done, apparently at this level. The Peterson or Red ore of Olive Furnace is a stratified ore, and probably of Upper Freeport age. It is worked by Olive Furnace. There needs to be added to the list one or two higher ores that have been at some time worked in the district. The Oak Ridge Furnace was run for the greater part of its brief history on an ore that is found 20 feet above the Cambridge limestone. The Banda ore of Gallia Furnace, and the Hallelujah ore of Mt. Vernon Furnace are also examples of this class. These last-named ores probably belong to the horizon of the Brush Creek limestone, to which the Dugway ore of the Hocking Valley has also been referred. The former is not now worked, but the latter is worked to a considerable extent at Mt. Vernon Furnace.

In the brief review to be made of the field, the above named divisions will be followed, beginning with the lowest.

(1.) Ores from the Sub-carboniferous Limestone to the Mercer Group, inclusive.—Lowest Division.

The best single section to represent this series is found on the lands of Scioto Furnace, Scioto county. But one addition needs to be made to the furnace section, in fact, to represent all the ores of the district, from the Upper Mercer limestone downwards. The section, which was furnished by Mr. Dudley Hutchins, of Scioto Furnace, and verified by our own work, is as follows:

		Feet.
8.	*Franklin Block ore*—{ Big Red block, Main block, Upper block; Upper Mercer ore.	258
	Interval, 12 feet.	
7.	*Sand Block ore*	246
	Interval, 38 feet.	
6.	*Little Red Block ore*—{ Blue Limestone block, Lower block; Lower Mercer ore.	208
	Interval, 40 feet.	
5.	*Boggs ore*—Flag ore	168
	Interval, 78 feet.	
4.	*Lincoln ore*—Covering Blue ore, Thompson ore, Kidney ore, etc	90
	Interval, 60 feet.	
.	*Blackband ore*—Sharon horizon	30
	Interval, 30 feet.	
2.	*Guinea-fowl ore*—Conglomerate horizon	0
(1.	Block ore of Maxville limestone.)	

The measurements are longer here than to the northward. The one ore to be added to the series is the block ore (No. 1), that is borne by the Maxville or Sub-carboniferous limestone. South of the Ohio River it becomes more regular and valuable, and is known as "limestone ore." It is of small account in Ohio, being seldom worked, except as an accessory element when the limestone is quarried or mined for furnace use. Harrison township, Scioto county, and Hamilton township, Jackson county, are the only localities that have produced any considerable amount of it. Its quality is good and its volume fair for a block ore, the thickness ranging from 4 to 8 inches, but the limestone horizon is itself one of the most inconstant of the series, and the ore does not extend beyond the limestone.

Its place in the series, when present, is but a few feet below the Conglomerate horizon, which makes the base of the series given above.

The Guinea-fowl ore (No. 2 of the section) has already been characterized, and requires no further discussion. It is a showy but worthless deposit. Its volume is good, reaching a maximum of 3 feet, but its quality excludes it from furnace supply. It carries, in addition to all the chemically combined silica of the ore, a large percentage of sand and quartz pebbles. Its place is upon the upper surface of the Conglomerate. It doubtless lacks persistency, as the stratum that bears it is very unsteady.

This section is mainly occupied by block ores, as has already been

stated, but there are two examples found in it of stratified ores. The lowermost one of these (No. 3 of the section), seems to belong to the horizon of the lowest coal. Blackband, as will be remembered, occurs at the level of this seam in Northern Ohio, and attains great value there, but no clear and well defined example of it has been reported south of Mahoning county. On the lands of Scioto Furnace, however, a few hundred tons of a stratified ore have been mined from the very floor of the Lower Coal Measures. There is no good development of the Sharon or lowest coal in the county, but the ore comes from the place where it is due. The deposit is not even or regular, and it is confined, so far as is now known, to a few localities. Exploration has been of a simple and inexpensive kind, and our knowledge is therefore mainly derived from a few outcrops. No analyses are at hand, but it is safe to say that the ore is low in iron. It has been tried in the furnace, but is no longer mined.

The most important fact in connection with this deposit is the reappearance of blackband at the Sharon coal level. Though this particular deposit has no great value, its presence dislodges the presumption against the occurrence of ore at this horizon, which the circuit of 200 miles, from which it is absent, has served to establish.

No other beds of this character are now known, unless the formation referred to in the subsequent paragraph as occurring in section 2, Richland township, Vinton county, shall be assigned to this place in the scale.

At 80 to 100 feet above the Conglomerate or the Sub-carboniferous limestone, and at 100 to 125 feet below the Lower Mercer limestone, in the southern part of the field, and at 75 to 100 feet further northward, there is a series of small ore deposits. Not less than five distinct names have been given to ores that have been opened and worked about Scioto Furnace at this general level. The best known of these names is perhaps the Lincoln ore, or No. 4 of the section. It matters but little whether there are one or five seams of ore in this series, for no one of them singly adds much to the supply of the district, nor do all combined.

The horizon is seen to be about that of the Wellston coal. This seam is often covered with heavy kidneys of ore, known as the Davis ore, near Wellston, and it is probable that these several ores of Scioto

county are contemporaneous with the coal formation of Jackson county, which was formed at the margin of the field.

At Franklin Furnace, long since dismantled, small benches, at this general level, show that a little ore was once obtained here. At Empire Furnace the same thing is true. Near Jackson Furnace, Jackson county, also, a seam of rough ore, running from 1 to 2 feet in thickness, was worked on a small scale when the furnace was in operation, at about 90 feet above the Conglomerate level. On lots 12 and 13, Lick township, Jackson county, a rough ore is found 80 or 90 feet below the Lower Mercer limestone. In section 9, Lick township, ore has been dug 60 or 70 feet below the same horizon. At Petraea, Jackson county, ore also appears at this level. In section 33, Washington township, Jackson county, rough ore has been mined at 80 feet below the Lower Mercer limestone. In Richland township, Vinton county, near Raysville, ore has been recently mined in a small way, at 70 to 80 feet below the Lower Mercer limestone. In section 25, same township, an ore, 2½ feet thick, is mined at the same level. In section 3, and also in 2, of the same township, there are quite conspicuous displays of ore at the same general horizon. The last-named locality shows the iron as approaching a blackband ore. Attention was called to this point by Dr. D. V. Rannels, of McArthur. This ore may belong to the next lower horizon, as intimated on a preceding page. In any case, there is a large amount of the seam throughout the township.

The statements that have been now given cover most of the facts as to the development of these lowest ores, and it is plain that they add but little to the mineral resources of the field.

Boggs Ore.

The next ore, No. 5 of the section, holds a very different place from those last described. It is a new ore, but it makes a valuable addition to the stock already known. In Bloom township, Scioto county, which is the most important center of its development, it is known as the Boggs ore, from the name of the farmer on whose lands it was first opened, but at Howard Furnace, in Vernon township, and also at Scioto and Bloom Furnaces, the same seam has been worked on a small scale for many years as the *flag* ore. This term suggests the nature of the ore. It is a stratified deposit, occurring in sheets or "flags" like sandstone or shale. It is not a blackband, as there is no

coal and but little carbonaceous matter in the seam, nor does it agree in appearance with the clay-bands of the Upper Freeport horizon. It consists mainly of gray carbonate of iron, interleaved with gray shale. The ore has excellent volume, reaching in the drifts a maximum thickness of 6 feet, and holding a thickness of 4 to 5 feet over considerable territory. Almost all that is now obtained is mined in regularly opened drifts. The chief center of its present production is at and about Webster, Bloom township. All of the ore from this field is taken by the Jackson and Wellston furnaces. The large and continued use of it at these points guarantees at least a fair quality to the ore.

This quality is further shown by the following partial analysis of the ore, furnished by Issaac Brown, Esq., President of Star Furnace Company, Jackson:

Metallic iron	34.7
Silica and alumina	22.4
Sulphur	0.231
Phosphorus	0 557
Moisture	4.6

Mr. Brown further states that the ore contains 3 per cent. of lime, that it loses 24 per cent. in calcination, and that the calcined ore yields in the furnace, in actual work, 48 per cent. of iron, which is a little better than the analysis above given indicates. He adds that the iron made from the Boggs ore is a strong, dark-colored, open-grained foundry iron of excellent quality. The only faults of the ore are its leanness, and the fact that it cannot be worked by itself.

In Vernon township it is thinner than in Bloom, but it still overmeasures the other accessible seams, with the exception of the Franklin block. It has long been mined by Howard Furnace as the flag ore. At Clinton Furnace, it is apparently replaced by a sandy limestone.

Promising outcrops of the seam are known in Hamilton township, Jackson county, and the so-called limestone ore of Richland Furnace is probably to be referred to this horizon.

A considerable supply of ore for many years to come, is to be expected from the Boggs seam. The two or three square miles at the center of Bloom township that contain it would of themselves warrant such a statement.

Its place in the scale is easily remembered. It lies about 40 feet

below the Lower Mercer limestone. The range of intervals is small, not exceeding 10 feet.

The only ore of the counties to the northward with which it can be correlated is the Junction City or Union Furnace block ore, and this possibly takes the place of the Lower Mercer coal. It is not claimed that this correlation is established on any stratigraphical connections between the fields, but the regular expansion of intervals to the southward would throw the Junction City ore about to the level of the Boggs ore in Scioto county.

Block Ores.

The three ores that are next reached in ascending order are by far the most important of the division, and are among the well-marked and well-known ores of the field. Two of them, moreover, are of the persistent class, coming into the present sections from every district which our review has thus far traversed. They are the block ores of the Mercer series. There are but two ores in the rest of the field, accompanying this group, but a third and intermediate one is added in the Hanging Rock district. The lowermost certainly covers the Lower Mercer or Blue limestone, the most wonderfully persistent little stratum of the entire geological scale of Ohio. It has more hundreds of miles of outcrop than it has feet in thickness. The uppermost of the three ores also frequently covers a limestone or flint, which matches in all respects to the Upper Mercer horizon, to which the flint and ore are referred. There remains an ore of frequent occurrence and quite wide distribution between these two ores. It is commonly known as the sandblock ore. It is generally nearer to the upper block than it is to the lower, being 12 to 20 feet from one and 25 to 35 feet from the other.

The lower block ore is known by several local designations. It is called the blue limestone block, in Jackson county, the little block and the fine block at other points. It is thin in southern Ohio, seldom exceeding 6 inches in thickness, and ranging where worked from 4 to 6 inches, but it is persistent, and its quality is steady and excellent. It is nowhere mined in drifts, but the benchings for it skirt a great many hills and a great number of miles of outcrop. All of the western furnaces, except Jefferson, use it, but none of them make it a reliance.

The middle ore or sandblock is on the whole a better ore than its name implies. Its use is not generally encouraged at the furnaces, but

Howard, Pine Grove, Scioto, the Jackson and Wellston Furnaces, all take a good deal of it in the course of the year. It is scarcely thicker on the average than the lower block. It yields at many points as mellow and excellent ore as any horizon of the series, but it is not reliable, and good ore is likely enough to run into a poor or worthless quality quite abruptly. It is rougher looking ore than the lower block, as a rule. A coal seam comes in occasionally, exactly upon its horizon, as will be shown in a subsequent chapter. This makes it probable that the ore replaces in part the coal of the Upper Mercer horizon. It is decidedly the least valuable of the three block ores.

The upper block ore has been named by Mr. C. N. Brown, the assistant who has done most of the work in this field, the *Franklin block.* It was the main reliance of Franklin Furnace during its whole existence, and moreover its westernmost outcrops are on the lands of this furnace, and it is nowhere better than at this point. Ohio and Pine Grove furnaces also put great dependence on this seam. It is known in the Ohio Valley as the main block, the others running under and thinning out as they go to the eastward, but this one holding its place in full force as far as Ashland, Ky. The more common designation for it is the *Big Red block.* By this name it is known at all of the southern furnaces where it has its best development. This name suggest one of the chief distinctions, and one of the trivial marks of the ore, viz., its size, and its color on outcrops. It ranges from 8 to 12 inches in thickness on Ohio and Pine Grove lands. At Ironton it measures fully 2 feet, but is very close grained and stubborn, and lacking in adaptation for use in charcoal furnaces, but Sarah Furnace of Ironton is at present using ore from this seam. At Bloom, Scioto and Monroe furnaces, and throughout Jackson county, it has a general thickness of 12 or 14 inches. The ore seldom fails where it is due, but it is sometimes too coarse and rough to secure approval. Good ore, however, comes in from this horizon at almost every furnace to which the seam is naturally tributary, and at some points the quality is excellent.

This ore has now been followed under one general name, and with quite uniform characteristics from the Ohio Valley to the Vinton county line. In Clinton and Elk townships of Vinton county, where it is known as the Craig ore, the Robbins ore, and the Huhn block, it holds substantially the same features as at the southward, but in Swan township it takes on new proportions, and has been found within the

last few years a proper basis for mining on a large scale. It is here known as the Dunkel ore, the Creola ore, and the Swan township ore. It is underlain with its limestone or flint through a considerable part of its area.

It has a maximum thickness of 24 inches, and it seldom falls below 16 inches in the extensive workings of the seam that have here been carried forward. The seam, however, consists of two benches, approximately equal in thickness, but of unequal quality, the upper portion furnishing the best ore, and the lower, which is quite silicious, being often rejected by the furnaces. The ore has a coarse and unpromising look, but the furnace men who use it pronounce it not only better than it looks, but a fair source of iron.

It has been mined thus far almost exclusively by stripping or "tailing." The ore diggings about Creola are the largest and deepest continuous benchings in the entire district. Immense quantities of the ore are of course left behind the benches, under the cover of the hills, and there is also a large quantity of outcrop ore still accessible, but at greater distance from the railroad than that already worked. The entire production is tributary to the Hocking Valley furnaces.

The remaining block ores of the series are entirely overshadowed in northern Vinton county by the Dunkel ore, but all three horizons of the block ores appear here.

On Abram Clark's farm, section 9, Elk township, we find the following section:

Dunkel ore—Franklin or Big Red block.	
Interval	13 feet.
Dever block—Sandblock.	
Interval	27 feet.
Blue limestone—Lower Mercer.	

The middle or sandblock ore, here known as the Dever block, has been mined to quite an extent on several farms near by, reaching the railroad at Swaim's Station.

From this point southward, the three block ores, as has been already shown, have a full development and hold their places with great regularity.

In closing the description of the ores of this section, the following recapitulation may be serviceable.

There are four important ores in this lower division, viz., the three

regular block ores and the Boggs ore. Their relations to each other and the general scale are shown in the following table, viz.:

Franklin block ore—Upper Mercer limestone horizon.	
Interval	10 to 20 feet.
Sandblock ore—Upper Mercer coal horizon?	
Interval	25 to 35 feet.
Little block ore—Lower Mercer limestone horizon.	
Interval	40 to 45 feet.
Boggs ore—Horizon of Junction City block ore? possibly Lower Mercer coal horizon?	

The maximum interval between the upper and lower block ores is 75 feet; the minimum is about 40 feet.

The longest measurement found is on the lands formerly owned by Junior Furnace, but intervals of 60 feet are not unusual in the Ohio Valley.

(2.) The Limestone Group or Middle Division of Ores.

There are only three worked ores in this division, but one of them, by itself, outweighs in value all the other ores of the field combined. The series is shown below:

1. Limestone ore—Horizon of Ferriferous limestone.	
Interval	15 to 25 feet.
2. Limestone kidney—Upper or Little kidney, Canary ore of Vernon township, etc.	
Interval	15 to 25 feet.
3. Limestone kidney—Lower or Main seam, horizon of Putnam Hill limestone.	
Interval to Franklin block ore	70 feet.

This series takes in the strata above the Franklin block ore to the Ferriferous limestone, including the latter. In vertical measurement, it almost always exceeds 100 feet. A few of the measured intervals are given below:

	Intervals.
At Ironton	107 feet.
At Lawrence Furnace	103 to 115 "
At Center Furnace	108 "
At Ohio Furnace	102 to 115 "
In section 23, Vernon township, Scioto county	133 "
At Bloom Furnace	118 "
In section 36, Lick township, Jackson county	100 "
In section 34, Swan township, Vinton county	100 "
In Hocking county	about 70 "

Many such measurements could be given, but the range and the average are well shown in those that are here reported.

It will be noticed that but one third of this series is productive. The lower 70 feet carry no ore nor limestone, and, it may be added, but very little coal. They are more barren of economic interest than almost any other equal space in the Lower Measures.

Limestone Kidney Ores.

The first ore to be reached in our ascending review is the Lower or Main Limestone kidney ore, the place of which is 30 to 40 feet, and sometimes, possibly, 50 feet below the Ferriferous limestone. The usual distance in the territory where it is worked is 30 to 36 feet.

It is not of wide extent, being confined in its most valuable phases to Elk and Clinton townships, Vinton county, and to Milton and Lick townships, Jackson county. At Lawrence Furnace, the so-called slate ore holds about the horizon of the limestone kidney. In all of its extent, a blue fossiliferous limestone, or a flint of like character, is quite likely to be found directly below the ore. This flint is well shown on the Feeogh farm, section 11, Elk township, and also on the Felton farm, section 27, Elk township. It is also found in some of the workings that are tributary to the Wellston furnaces. A coal seam that occurs a few feet above the ore, is well developed in Elk township, and is here known as the Winters coal, and also as the Flint Vein. It is probably the Conway coal of the Ironton region.

The ore consists of massive and close-grained, symmetrical concretions. Under cover they are blue and hard and heavy. On the outcrop, they furnish one of the finest ores of the series, scarcely inferior in any respect to the standard limestone ore. The horizon yields 10 or 12 inches of ore, as a rule, and often exceeds this. In the vicinity of Wellston it sometimes is found 2 feet thick. The ore is nowhere mined in drifts, so far as known.

The next ore is of small account. It is mellow and excellent, but there is not enough of it. It is known as the Little kidney in Vinton county, to a few townships of which it is limited. It seldom reaches 6 inches in thickness. Its place is 15 feet below the Ferriferous limestone. It makes the red ore of Ilesboro, Washington township, Hocking county, and is there granular, like the regular limestone ore. This last instance is the only one in which the ore is known to be worked north

of Vinton county. In the latter county it is mined in Elk and Brown townships to a small extent. In Lawrence and Scioto counties it has also long been worked in a like small way. It is here known as the Canary ore. Its position is about 25 feet below the Ferriferous limestone. The seam does not invite nor warrant large work, and it cannot be said to make an important contribution to the iron making resources of the district.

Limestone Ore.

The last and main ore of the division is so well known, and has been so often characterized already in the geological reports of the State that no extended description is here called for. The Ferriferous limestone that bears it, is itself of great value and importance to the whole district, yielding almost the entire supply of furnace flux and lime. The thickness of the limestone exceeds 5 feet through most of the territory that contains it, and sometimes reaches 10 feet. It is exceedingly regular and persistent, leaving but few wants throughout its field. It can be followed almost without a break from the Ohio River hills to Brown township, Vinton county.

The ore has been quite fully described in vol. III, pages 905–6, and also on pages 404 and 413 of the present chapter. It now remains to point out its chief development up to the present time.

In the first place it is to be noted that, like its limestone, it is an unusually persistent element. The chief "wants" or breaks in its continuity are the following:

About Hanging Rock, and thence to the east of Pine Grove Furnace, taking in the site of La Grange Furnace, long since dismantled, there is found one of the largest of the districts that are wanting in the ore and limestone. The failure of the ore was in fact the cause of the abandonment of La Grange Furnace. A large part of Pine Grove lands lacks both limestone and ore.

Again, on Storms' Creek, above old Vesuvius Furnace, a considerable "want" has been proved in the ore. There are several square miles of unproductive ore ground here.

On Raccoon Creek, in Vinton township, Vinton county, along the Ohio and West Virginia Railroad, the limestone is very irregular, disappearing very frequently from the sections. The ore is equally unre-

liable. On Wheelabout Creek, in Madison township, it is also extremely uncertain, but both of these stations are near the northern limit of the main sheet. In Brown township it has passed the limit, and beyond Hope Furnace neither limestone nor ore have been found to the eastward. Northward, the limestone is small and uncertain through Swan and Starr townships, but its ore is persistent and valuable. This part of the field has been previously described.

The following notes indicate the chief centers of past and present production:

Lawrence County.

Hamilton township, section 8—western outcrop.
" " near Newcastle—Ore irregular (near boundary of want already noticed.)
Upper township, largely worked.
Elizabeth township—
Township 2, section 3, 4, 8, 16, 17, 19, 20, 21.
Township 3, " 31.
Decatur township—Universal.
Washington township—Universal.
Symmes township, section 8—Present in small area, not mined.
Lawrence " " " " "
Perrry " " " " "

Scioto County.

Green township—1½ miles northeast of Haverhill, western outcrop.
" " Ohio Furnace lands, western outcrop.
Vernon " Sections 23, 24, 25, 26, 34.
Bloom " Section 30, western outcrop.

Jackson County.

Jefferson township—Sections 15, 24, 36, etc.; occupies one-half of township, very largely worked.
Madison township—Sections 3, 4, 5, 7, 8, 10, 15.
Bloomfield " " 11, 12, 13, 14, 29, etc.
Lick " " 23, 35, 36.
Milton " " 2, 4, 15, 19, 20, 21, 22, 25, 26, 28, 30, 35, 36.

Gallia County.

Greenfield township—Sections 9, 11, 16, 20, 30.
Raccoon township—Struck in boring in section 19, at Centerville.

VINTON COUNTY.

Wilkesville township—Section 33, etc.
Vinton township—Sections 4, 16, 33. Fractional sections 1, 5, 6, 19.
Clinton township—Sections 3, 6, 9, 13, 21, 23, 27, 28, 29.
Madison township—Section 33.
Elk township—Sections 15, 17, 22, 27, 30, 31, 36.
Richland township—Section 13.
Brown township—Fractional section 19.
Swan township—Section 34, etc.

This list of working localities is far from complete, but most of the chief centers are included. The ore throughout the area here named has a working thickness of about 10 inches for the main seam. In favored localities it rises to an average of 12 inches for large tracts. Washington Furnace lands, and portions of Vinton township, as the Tarr farm, show this thickness in the main seam. Where the ore is mined by stripping, the kidneys will often add several inches to this measure. The ore swells up in rolls to 2 and 3 feet, and sometimes to even a larger volume, but it is the steady seam that the furnaces have learned to value, inasmuch as the rolls are likely to be followed by "pinches." The ore is mainly got by drifting at the present time, the outcrops having been carried back to quite heavy banks in most of the furnace tracts. Etna Furnace is drifting for the kidneys overlying the main seam, which is here lighter than usual. The drifts are four to five feet in height.

This is the seam from which more than 50 furnaces of Ohio and the adjacent district of Kentucky have obtained, and many of which are still obtaining, their chief ore supply, some of them through two or even three scores of years. The iron made from it is the standard iron of the Ohio Valley, for many uses. For strength and chilling qualities it is at the head of the list, a considerable amount of it being used in car-wheels and in machine castings.

(3.) The third and last division of the Hanging Rock ores remains to be described. It includes, as will be remembered, all of the ores that are or have been mined above the limestone ore. From the limestone ore to the highest of this group, the vertical distance is but little less than 300 feet, but the ore which we find at this extreme elevation has little or no value, and is not likely to be mined in time to come. At 175 feet above the limestone ore, there is an ore horizon that is worked to a considerable extent by one or two furnaces. This may be

counted the real limit of the series. The ores of which account should be taken, are the following:

7. Oak Ridge ore.
   Cambridge limestone.
      Interval .... 120 feet.

6. { Hallelujah ore of Mt. Vernon Furnace.
   { Banda ore of Gallia Furnace.
      Interval .... 20 feet?

5. Peterson ore of Olive Furnace (Waterloo or Upper Freeport coal? No. 7).
      Interval ....10 to 15 feet?

4. Little Yellow kidney ore.
      Interval ....40 to 50 feet.
   Hatcher or Lower Freeport coal, No. 6*a*.

3. Yellow kidney ore.
      Interval ....40 to 50 feet.
   Sheridan or Middle Kittanning coal, No. 6.

2. Black or Red kidney ore.
      Interval ....20 to 30 feet.

1. Phosphorus ore of Hamden Furnace.
   New Castle or Lower Kittanning coal, No. 5.
      Interval ....25 to 35 feet.
   (Limestone ore.)

Of these seven ores the first and the last make no addition to the resources of the district, but they demand a place in the series because they have been mined and worked to some extent. Questions may be raised as to numbers 4, 5 and 6. They occur in close proximity, and some may be inclined to refer them to a common horizon, but the separation indicated above seems, on the whole, to express the true order. Positive statements are not warranted in regard to this matter. To correlate them with the series of the Hocking Valley, the Little Yellow kidney must be referred to the horizon of the Straitsville ore; the Peterson ore would then represent the Upper Freeport or black-band horizon, and the Hallelujah or Banda ore would come in at the horizon of the Dugway ore, which probably belongs at or near to the horizon of the Brush Creek limestone. The leading members of the series are Nos. 3 and 2. Each member of the group will be briefly characterized.

The so-called "Phosphorus ore" of Hamden Furnace is an ore of good volume and appearance, but it runs so high in phosphorus, that it cannot be counted a proper source of pig iron. Some analyses of it

report 7 to 8 per cent. of phosphates, almost enough to give it value as a fertilizer. It has been worked only on the lands of Hamden and Pine Grove Furnaces. On the former tract it ranged from 2 to 4 feet in thickness. Its appearance was good, and quite a large amount was mined before the real character of the deposit was discovered. Pine Grove Furnace had quite a similar experience. Within the last few years the ore was found on the furnace lands. It had fair thickness, and its general appearance was excellent, but in the furnace it proved mischievous to a high degree. The percentage of phosphorus probably exceeds that of the ore as found at Hamden Furnace.

The place of this ore in the scale can be easily remembered. It lies directly above the Lower Kittanning coal (No. 5), or at the very base of the Kittanning shales. This is also the position of the blue block ore of Tuscarawas county, but the horizon is not worked in the State, except at these three points. The so-called blackband of Holmes county belongs at this horizon. A heavy deposit of ore on the Cherry farm, in the southern part of Starr township, Hocking county, is perhaps referable to it also.

Black Kidney Ore.

The kidney ore that lies next higher in the series has various names in the several parts of the field. It belongs a few feet below the Middle Kittanning (or No. 6) coal, and from 50 to 55 feet above the Ferriferous limestone. This horizon is as persistent as any ore horizon of the Lower Coal Measures. It has now been traced continuously from the Pennsylvania line to the Ohio River. In the Hanging Rock district it is known by two names, viz., black kidney and red kidney. In the Hocking Valley it is the Snow Fork kidney. In Tuscarawas county it is "Shell ore," and in Columbiana county it is known simply as kidney ore. There is, in fact, no part of the field where the shales that intervene between the Kittanning coals do not carry a notable quantity of iron ore.

A little ore is taken from this seam in the Hanging Rock district on several furnace tracts. Across the river, in Kentucky, it is mined quite largely, where it is generally known as the Red kidney. The ore occurs in fairly regular concretions of moderate size. When the weathered ore is broken, black seams are often found traversing it, and from this fact one of its common designations is borrowed. It is well

esteemed as a source of iron, but the horizon does not repay extensive work in Southern Ohio.

Yellow Kidney Ore.

A much more valuable ore, and the only seam of the entire series that is worked at a considerable number of localities, is the Yellow kidney ore. Its place is 90 to 100 feet above the Ferriferous limestone, or from 40 to 50 feet above the ore last named. It belongs to the horizon of the Lower Freeport limestone, sometimes replacing it, and sometimes accompanying it. The kidneys are found scattered through 4 to 6 feet of shale, and when all are counted, the aggregate ranges from 6 to 10 inches in thickness. The ore is valued as highly as any that comes to the furnaces of the district. It can be mined only by stripping, and consequently the ore is at its best. The diggings are nowhere extensive, but the seam is opened at a great number of places. This ore underlies the Lower Freeport or Hatcher coal by a few feet. It is most largely worked on Howard and Buckhorn lands, but it is also mined in considerable amount by Centre, Olive, Mt. Vernon, Hecla and Little Etna Furnaces.

At 40 or 50 feet above the Yellow kidney, and therefore at 130 to 140 feet above the Ferriferous limestone, another kidney seam is found that has been worked at a few localities on a small scale. It is known as the Little Yellow kidney. The quality is good, but its volume is too small and its occurrence is too uncertain to render it an element of economic interest. It is assigned provisionally to the horizon of the Upper Freeport limestone, or possibly to the place of the Buchtel ore.

Peterson Ore.

The Peterson or red ore of the Olive Furnace seems to belong to the blackband horizon of the northern counties. It is a stratified ore, and a coal seam is found directly associated with it, sometimes cutting it out altogether. Its elevation is about what the Upper Freeport horizon calls for. The section is as follows on Olive Furnace lands:

Buff limestone—Brush Creek	162	feet.
Peterson or red ore (130–143)	130	"
Buff limestone and ore—Upper Freeport	110	"
Coal blossom—Lower Freeport	92	"
Coal—reported Middle Kittanning	65	"
Coal—Lower Kittanning	20	"
Ferriferous limestone	0	"

The ore is known only on the lands of Olive, Buckhorn, and Mt. Vernon furnaces. It is mainly worked by Olive Furnace, but Buckhorn is also mining a little. It ranges from 1 to 2 feet in thickness, and mines very small, being little better than dirt in appearance when it comes to the furnace. Care has to be exercised in charging it, on account of this fine division, several serious accidents having already occured in its use. The seam is steady and justifies mining on quite a large scale, both by heavy benching and by drifts. The mining of the ore is going forward continuously.

Olive Furnace counts the ore essential, especially in the manufacture of car.wheel iron. A mixture of it with the other ores of its supply is found to impart the chilling property required for this grade of iron. A considerable importance is thus seen to belong to this horizon.

Hallelujah Ore.

The Hallelujah ore of Mt. Vernon Furnace lies, according to the best interpretations, a few feet above the blackband level, but upon this point there is room for difference of opinion. It may prove to be upon the blackband horizon, with the ore last named. Wherever it goes, will probably also go the Banda ore of Gallia Furnace, an ore once mined in considerable quantity, for a short time. Neither of these ores is distinctly stratified, and yet both agree with this class more nearly than with any other.

The Hallelujah ore has large volume for a Hanging Rock ore, ranging from 1½ to 2 feet in thickness. It is red on the outcrop, but under cover it is blue with a greenish tinge. Thus far it has been worked only in one hollow of Mt. Vernon land, but the same ridge that covers it reaches through to Buckhorn land, and it will probably be found here also when looked for.

The ore imparts a peculiar character to the iron into the production of which it enters, causing it to crystalize in large plates, like spiegeleisen. For some time this character of the iron worked against it in market, but latterly a demand is said to have arisen, the nature of which is not now apparent.

The last ore of the series scarcely deserves a place in the column. The Oak Ridge ore was discovered, it might almost be said, invented, to meet the demands of a newly built furnace that was located outside

of all the main ore belts. Something must be found from which to make a stock pile, and the Oak Ridge "ore" answered for this purpose, and it also served to use up the charcoal supply of Oak Ridge Furnace during its first and only blast. The ore lies about 20 feet above the Cambridge limestone. It is a lean and coarse deposit, kown in but a small territory and not likely ever to be mined again as a source of pig-iron.

This completes the review of the main horizons at which iron ore is or has been mined in the State. Several of these horizons have been found to be strictly continuous, and but few of them are limited in their extent to a single locality. Even those ores that are most restricted, generally come in at the horizons of other vital elements in the series, as coals and limestones, and thus the anomaly of their occurrence, to a certain extent, disappears.

The composition and adaptation to furnace use of these several ores have been treated only incidentally in the present chapter. These subjects will be more fully discussed in the following chapter, where also the general conditions of iron manufacture in Ohio will be considered.

PROFESSOR EDWARD ORTON, *Chief Geologist:*

SIR: I beg leave to submit the following report on iron smelting in Ohio. The review is as complete as it was possible to make it in the limited time at my disposal.

The work of Mr. Henry Newton, who prepared a portion of the report, and in whose death some years ago the Survey lost so valuable an assistant, comprises possibly a fourth of the report, but it was necessary to review and bring up to date the work almost over the whole field, and for this purpose but a month or two could be applied in the field; it is hoped, however, that the industry has been fairly outlined, and sufficient chemical and analytical work been done to fairly illustrate the problems involved and the direction in which improvement may be looked for.

In preparing this report, I have availed myself of the published statistics of the "American Iron and Steel Association" and the "Census Bureau." The work in the field has been not only facilitated but made possible by the kindness of several of the prominent Furnace Companies in the State, who have furnished me with drawings, figures and other material.

Very truly yours,

N. W. LORD.

CHAPTER VI.

By N. W. Lord.

IRON MANUFACTURE OF OHIO.

GENERAL CONDITIONS.

There are few territories of equal extent with the State of Ohio, that are so abundantly provided with the means of industrial wealth. The great fertility and yield of her agricultural regions have long been known, and the cultivation of her rich valleys has given prosperity and riches to a large population. Concerning, however, the character and utilization of the immense stores of coal and iron, locked up in the rocks of the Coal Measures, which underlie so large a portion of the State, the general information has been limited in extent and accuracy. Nevertheless, private explorations and private enterprise have developed an industry in the manufacture of iron, which places Ohio second only to Pennsylvania among the iron producing states of the Union. A full knowledge of the occurrence and character, and an intelligent employment of these raw materials, the coals and iron ores, so pre-eminently the foundation of the necessities and comforts of our age, becomes a matter of the very greatest importance to a people possessing them. And the work of the present Geological Survey, in collecting and generalizing the facts observed relating to those mineral staples, and their use in our own and other States and countries, must afford a firm basis for the certain and rapid progress of the manufactures dependent upon them. Information, which too often has been the exclusive property of the invester, will be thus accessible to both the owner of the land and the capitalist who develops the riches beneath it, and this information, so long wanted, will redound to the common interest and the prosperity of the State. A knowledge also of the principles involved in the manufactures, raising the coals and iron ores, and the method and apparatus employed elsewhere in our own and other countries, it is hoped, will favor a more general appreciation of the applications of science, skill and accuracy to these manufactures.

All the iron ores of any value in Ohio are found among the rocks of the Coal Measures, and although they are quite abundant in this formation, it is only in a few regions that they are in sufficient quantities to sustain important iron industries, so that the chief supply of ores is now, and will be, obtained from other States. The rich and pure specular ores of Lake Superior, the magnetites of Canada, etc., readily transportable by the waters of the great lakes to her northern shores, meet first in the coals of Ohio the supply of fuel, in which those regions are so deficient. Hence it is that the coals of Ohio are the most important element in her mineral industry, and the one upon which the existence and progress of Ohio as an iron manufacturing State must, of necessity, be mainly dependent. The character and extent of the Coal Measures has already been most thoroughly discussed in portions of the geological reports, and the continuation and value of each seam of coal and deposit of iron ore traced in all their variations of importance through the entire area. The geological map already published by the Survey, and the local maps of the present volume, exhibit the extent of this area in Ohio. The various points of the manufacture being denoted, their relations to each other, to the different parts of the coal area, and to the various means of transportation, will be readily appreciated.

The iron manufacture of the State is divided into several districts, and a description of the peculiar conditions is given in another place of each region separately, with quite full details, referring to their situation and relations, the fuel area as used, the furnaces and their economy, the general facts of the methods of working, and the character and uses of the iron produced. It is intended, however, to make a summary of the general conditions of iron manufacture in the State, under the following heads, namely: Means of transportation; general character of the Coal Measures in Ohio; the fuels used, their characters, etc.; the different ores employed; general facts and results of the blast furnace practice; and finally, statistical facts regarding the manufacture in the State. The districts and places where the manufacture of iron is principally carried on, are situated in the eastern part of the State, as all the mineral fuel employed is derived from the coal measures which underlie the eastern third of the State. Facilities of transportation, the existence of other industries or large communities, however, are creating important iron manufacturing establishments at considerable distances from

the supply of fuel, as at various points along the lake shore, etc. The principal points, nevertheless, of the iron industry of the State will be within the limit of the coal area, or closely connected to it by railroad communication. While the districts and chief centers of the manufacture will be spoken of more fully at another place, brief mention may be made here of those towns which stand foremost in the iron industry of the State. First—Cleveland, on the shore of Lake Erie, is the great seaport or distributing place of the ores of Lake Superior, Canada, etc., for Northern Ohio and Western Pennsylvania, as well as being the commercial center for the iron manufacture of Northern Ohio. It also possesses itself large iron works, which are destined to be multiplied greatly, and make the Cleveland district of Ohio a great manufacturing center, a rival to its namesake, the celebrated Cleveland district of England, besides being the principal source for supplying the markets accessible by the chain of the great lakes. Second—Closely connected by railroad and every interest, Youngstown, in Mahoning county, is the chief town and manufacturing center of the celebrated region of the Mahoning Valley, and for real enterprise and quantity of product this region leads the manufacture in the State. Third—Steubenville, on the Ohio river, is the seat of an important iron industry, which is more closely connected in conditions of manufacture and interests with Pittsburgh than with Cleveland. Fourth—The Ohio towns, Martin's Ferry, Bridgeport and Bellaire, opposite to Wheeling. These towns and Wheeling, though now occupying a minor position in the iron manufacture on the Ohio river, by the unusual facilities which they have for water and railroad communication, and the enormous supplies of fuel in the great coal seam, which is everywhere visible in the vicinity, must soon occupy a pre-eminent one in this manufacture in the valley of the Ohio. Fifth—Ironton, in the extreme southern part of the State, on the Ohio, in Lawrence county, is now the center of the celebrated Hanging Rock region, and an important point of manufacture. The circumstances of the supply of ores and fuels, transportation, etc., more fully alluded to when describing the region, offer such conditions that we may anticipate for it progress and high position among the manufacturing towns of the State. Beside these chief points mentioned, there are others whose importance is not so great, as Leetonia, in Columbiana county, Massillon or the Tuscarawas Valley, Zanesville, Jackson, Columbus, and the Hocking Valley. On the lake shore,

besides Cleveland, there are several places yet almost unknown as manufacturing points, where the facilities of communication with the supply of fuel from the coal area and the ores from the lakes seem to present very favorable conditions for successful industries, as Painesville, Ashtabula, Black River, Sandusky and Toledo. At the latter place, however, there are already successful enterprises in operation.

Transportation.

In the modern manufacture of iron there is hardly any problem of greater importance than that of transportation, in the distribution of the ores and fuel, and marketing the products. Whether it is more economical, in any given case, to carry the ores to the fuel or the fuel to the ores, or to establish the manufacture at an intermediate point, are questions depending upon so many considerations, as to the relative expense of transporting the ore and fuel, cost of labor, the position of large manufacturing centers or markets, that they demand the most careful investigation before the erection of expensive establishments.

Before the conception of the vast railroad enterprises of the present time, the extensive canal system of Ohio was a subject of just pride to its inhabitants. But the railroad, in its rapid extension over the State, either by rivalry or by purchase, has reduced these expensive canals, with but very small exceptions, to the state of dry ditches, and as means of communication they have become things of the past. Though without any navigable stream within its own limits, Ohio, with the waters of the great lakes washing its northern shores, and the broad and navigable Ohio bordering its southern limits, has an extent of water communication which gives it almost the advantages of a sea-coast. By Lake Erie, the great lakes and the St. Lawrence, its vessels may pass from Duluth, at the extreme west of Lake Superior, to Quebec and the Atlantic Ocean on the east, a distance of 1,500 miles. While by the Ohio River it has a ready communication to all the points from Pittsburgh to St. Louis, and the Mississippi River to New Orleans, a distance of 2,090 miles. All the ores of Lake Superior are shipped either at Marquette, on Lake Superior, or from Escanaba, on Green Bay, Lake Huron, in barges, sailing vessels or steamers, many of which are built especially for the traffic, and as return cargoes they take back coal. Owing to the length of the winter in this northern region, the traffic lasts but a portion of the year, from about May 1 to Nov. 1.

At Cleveland almost all the sale of these ores is conducted, and while portions of the ores are delivered at various other places on the shore of Lake Erie, Detroit, Erie, Buffalo, etc., by far the largest proportions are received and transhipped at Cleveland, from whence they are distributed by railroad to Pittsburgh and other places in Western Pennsylvania, and at the many points in Ohio, etc. Beside the Lake Superior ores, considerable quantities of the Canadian ores from Lake Ontario, north of Kingston, of the Lake Champlain ores of Northern New York, and small proportions of other ores from the States, etc., bordering on the lakes, are received at Cleveland, and likewise distributed to the various points of manufacture with which she is in communication.

The following table shows the total receipts of iron ore in Cleveland from Lake Superior for ten years ending, 1871 to 1881, in tons:

1871	395,721
1872	622,059
1873	674,324
1874	456,692
1875	245,801
1876	141,268
1877	505,974
1878	509,332
1879	525,402
1880	718,983
1881	826,419

These figures are from the report of the Cleveland Board of Trade for 1882.

Cleveland is also a shipping place for very large quantities of coal, which is distributed to various points on the lakes from Buffalo to Chicago, Marquette and Duluth. The cost of lake transportation is low, but somewhat variable. During June, 1882, the freight for water transportation of iron ore was, from Marquette to the Lake Erie ports, $1.25 per ton, and from Escanaba, $1.00.

The Ohio River, which borders the southeastern and southern part of the State, is the great natural highway for the products of the Ohio Valley, and is navigable for its entire length from Pittsburgh to the waters of the Mississippi. The demand which is made by the Ohio Valley for a cheap and certain mode of transportation is impressing every year more and more strongly the necessity for some permanent

improvement in the navigation of the Ohio River, and whatsoever that system may be, it must eventually be carried out, to the no small advantage of the country bordering its passage. The railroads will be employed where cost can be sacrificed to the rapidity of transportation, but for the products of the soil, the mines and the iron works, the waters of the river are the true conveyor. And, the dense population which the valley of the Ohio is destined to sustain, will require the greatest obtainable facilities of the Ohio, as well as all the present and many more railroads. The chief importance of the river in its relation to the present iron industry of Ohio, is the means which it affords for the importation of the Missouri iron ores, the carriage of coal, etc., from one point to another, and the shipment of its crude and finished products to the various markets from Pittsburgh, Cincinnati, Louisville, etc., to the waters of the Mississippi. Thus the various iron works at Ironton, Wheeling, Steubenville, etc., on the river banks, have a ready means of communication with the Missouri ores, the coals and markets which always give to places so situated on an extensive system of water intercourse many advantages above those located inland. Though as a carrier, the river is of course slow in comparison with the railroads, still this inequality is rendered less when the lower cost and the much larger bulks which may be moved at once are considered.

The railroad systems of Ohio are the connecting links of the great trunk lines between the country of the west and northwest, and the Atlantic sea-board, and in their numerous crossings and interlocking they cover the State like a net-work, and connect together the remotest corners.

The Fuels.

The magnificent forests which covered the country west of the Alleghenies, at the time of the early settlers, provided a cheap and abundant source of fuel for smelting purposes, when the needs of the inhabitants demanded it. However, the rapid growth of the population, the clearing of the forests for agricultural and building purposes, together with the demands of the iron smelter, soon compelled the iron-masters to look elsewhere than to charcoal for fuel, so that now coal has replaced the use of wood where iron is smelted throughout the State, excepting in the extreme southern part, and in a few localities in the northwest, where it is still conducted. Notwithstanding that the manu-

facture of charcoal pig-iron is still a very important industry in Southern Ohio, it does not require much foresight to see that its importance is on the wane, and that ere long it must necessarily yield to the use of mineral fuel. Such has been the history of all the great iron manufacturing regions of the world when coal was accessible. Thus England, which in 1788 had 24 charcoal furnaces out of a total of 77, in 1872 had less than 5 in a total of 950. In the United States, east of the Alleghenies, the use of charcoal as a blast-furnace fuel has been or is being entirely superseded by mineral fuel, and such must be the result whenever the facilities of obtaining coal render its use possible. Considering, however, the supply of timbered land which Ohio still possesses, and the high value of charcoal pig-iron, this industry will be of some importance for considerable time to come. By a system of care, and strict economy in the use of the wood, and the employment of the best and most approved modes of manufacture, its duration can be lengthened, though the final fate of the industry is certain.

It may be safely stated, that at present (1883) eight-ninths of this available timber land of the Southern Ohio iron manufacturing districts has been cleared. Many furnaces are compelled to obtain their fuel from such a distance that its transportation becomes a very serious item in the cost of the iron made.

The Coal Area of Ohio.

Although this subject has been very fully treated in the Geological Reports, still, considering the primary importance of the coals in the iron manufacture, and the fact that all the points of the industry must draw its supplies from this area, and be situated in close relation to it, or actually within its limits, a brief summary of the general limits and character of the Coal Measures in Ohio can hardly be amiss here.

The line which bounds the Coal Measures in Ohio will include the eastern third of the State, or an area somewhat more than 10,000 square miles. This boundary line enters the State from Pennsylvania in the southeastern corner of Trumbull county, and then runs southward to near Youngstown, and westward to Ravenna, with a long span extending northward into Geauga county. From Ravenna the boundary passes near Akron, Summit county, and then pursuing a more southerly and sinuous course it runs near the east line of Knox county, passing near Newark, Logan, and finally crosses the Ohio into Kentucky, near

the mouth of the Little Scioto River, a few miles east of Portsmouth, in Scioto county. There are thus included within the area of the Coal Measures the whole or very nearly all of 22 counties, namely: Mahoning, Columbiana, Stark, Holmes, Tuscarawas, Carroll, Jefferson, Harrison, Coshocton, Guernsey, Belmont, Monroe, Noble, Muskingum, Perry, Morgan, Washington, Athens, Meigs, Jackson, Gallia and Lawrence, and portions of 14 others, namely, Scioto, Vinton, Hocking, Fairfield, Licking, Wayne, Medina, Summit, Portage, Geauga and Trumbull, and a few detached outliers in Knox, Richland and Ashland. This large area is only, however, the northwestern margin of the great Allegheny Coal Basin, the largest and most important of our American coal fields, which extends over portions of Western Pennsylvania, West Virginia, Eastern Ohio and Kentucky, and in a narrower belt passes through Eastern Tennessee, and terminates in the Black Warrior, Cahawba and Coosa basins of Northern Alabama. The whole extent of this great coal field in a northeast and southwest direction is about 875 miles. The broadest portion, which is across Central Ohio and Pennsylvania, is nearly 180 miles, while in Tennessee it is narrowed to 70 and 50 miles. The total area has been estimated as 59,105 square miles. The estimated area in the several States is as follows:*

West Virginia and Virginia	16,000	square miles.
Pennsylvania, excluding anthracite basins of Central Pennsylvania, 12,302, inclusive	12,774	"
Ohio	10,000	"
Kentucky	8,983	"
Alabama	6,000	"
Tennessee	5,100	"

Ohio may thus be seen to possess a very fair proportion of this coal field, and to have an area but little inferior to Pennsylvania in extent. This is an area nearly equal to that of all the coal fields of Great Britain, which have been estimated at 11,859 square miles. However, there is a fact too often disregarded when comparing our coal areas with those of Europe, etc., which is, that while the entire vertical thickness of the Coal Measures in the United States is not more than 2,000 feet, the English basins make up to a great extent what they lack in superficial area by their greater depth, in some cases being 12,000, and generally above 5,000 feet.

* C. H. Hitchcock, tenth census.

The rocks of the coal strata in Ohio lie nearly horizontal; they are subject to no great uplifts or faults, and while the dip varies considerably, it rarely exceeds 30 feet per mile in a direction south of east. The axis or central line of the whole Allegheny basin is found to pass near Wheeling, in West Virginia, in a northeasterly and southwesterly direction, and in the vicinity of Wheeling we also find the greatest vertical thickness of the coal Measures, which is abont 1,500 feet.

The strata of the Coal Measures are the most recent of the consolidated rocks of Ohio, and never were submerged after the time of their formation long enough to receive the deposition of any subsequent strata. They have hence been subjected for untold ages to the powerful denuding action of the atmosphere and water. Ceaseless erosion has probably removed the coal rocks from considerable areas which they once occupied, and has deeply furrowed the present area with innumerable valleys, which at one place or another expose to view the entire series of the Coal Measures. These valleys are often 400 feet below the summits of the adjoining hills. Their excavation has brought the deepest coals of the series within 800 feet of the surface, and exposed the various coals and iron ores on their slopes, in position which render their accessibility for ease and cheapness of exploitation unsurpassed. The exposures are so frequent and numerous that there is hardly a township in the entire coal area where coal is not drifted for, to supply the wants of the inhabitants; indeed, it might almost be said that each farmer has his own coal bank.

The total thickness of the coal bearing rocks in Ohio, as already stated, is about 1,500 feet, though over the greater part of the area the thickness is hardly more than one-half of this. The total thickness is divided by some 400 feet of barren shales (the Barren Coal Measures) into the coal groups of the Lower and Upper Coal Measures, which distinction holds with great completness over the whole area of the Allegheny coal field. The labors of the Geological Survey have recorded eleven workable seams in the Lower group—one at the base of the Barren Coal Measures, and six in the Upper group, or eighteen workable seams in all. These coals vary from 3 to 6 or 7 feet, and sometimes 10 feet in thickness, no seam being considered as generally workable where the thickness is below 3 feet. Beside these eighteen principal seams of coal, there are others intercalated, which, however, are generally of only local extent and importance. These coals have been

numbered consecutively from the base of the series, and their relationships may be readily understood by reference to the general section of the Coal Measures in Ohio.

The Coal Measures are composed of alternating strata of coal, iron ore, limestone, sandstone, fire-clay and shale. And thus, beside containing large supplies of coal, they include some valuable ores of iron, building material, limestone, quite generally distributed and sufficient to supply all the demands of iron works for flux and lime, and not least the fire-clays from which are made ordinary fire-brick, glazed ware, etc. In some localities a peculiar variety of fire-clay occurs, which is made into fire-bricks, which are unexcelled for durability and refractoriness by the celebrated Mt. Savage brick, of Maryland, or any other made in the country. The aggregate thickness of the coal seams in the Lower and Barren Measures is about 40 feet, and in the Upper Coal Measures 20, or approximately 50 feet in all, though as the Coal Measures are only of this maximum thickness in a small portion of the State, the available thickness of coal in the State is much less, probably not over one-half of this.

The lower group of coals contains by far the most important part of the mineral wealth of the Coal Measures in Ohio. They include all the most valuable furnace fuels and the only deposits of iron ore of any note in the State. At least three quarters of the coal area in the State have them as the surface rocks, while they are also more or less deeply buried under the Upper Coal Measures, which occupy the remainder of the coal area. The Geological Survey have recorded in this group six workable seams of general distribution, beside several others, which are locally thick and valuable. And their relation and thickness may be seen by referring to the geological section of the Coal Measures.

The Manufacture of Iron in Ohio.

The history of the iron industry in Ohio begins with the erection of a blast furnace at Poland, Mahoning county, a few miles southeast of Youngstown. This furnace was founded by Messrs. Montgomery, Clendenin & McKay, in 1806, and began to make iron in 1808. It was a small charcoal furnace, 30 feet in height and 7 feet across the boshes, cold blast and blown by water-power, producing only about two tons of iron per day. The iron made was principally cast directly from the furnace into various forms, such as pots, kettles,

etc. The ore used was the nodular clay-iron-stone of the coal measures. The furnace was built against the side of a hill, the rock of which formed one side of the furnace, was twice rebuilt, in 1816 and 1837, and after making a few blasts was finally abandoned. The ruins of this pioneer furnace in the Ohio iron industry are yet visible, near the old Mt. Nebo coal mines, below Youngstown. In 1809, James Heaton erected a charcoal forge near the present city of Niles, which produced from the pig-iron of the Yellow Creek furnace the first malleable or bar iron made in the State. In 1811–1812 the second furnace in the State was built by James Rogers and others on Brush Creek, about 12 miles from the Ohio river in Adams county. It was a cold-blast charcoal furnace, using a limonite ore found in pockets in the Niagara limestone, which, according to Prof. Locke, is the product of the oxidation of nodules of iron pyrites, which are quite abundant at that horizon. In the same year, 1812, James Heaton built the Mosquito Creek furnace at Niles, near the forge he had already erected in 1809, and in the following year, 1813, Daniel Eaton & Sons purchased the old Yellow Creek or Poland Furnace, and built another at Yellow Creek Falls, a few miles south. In the southern part of the State, in Adams county, the furnace built on Brush Creek was followed in 1816 by two other cold-blast furnaces in the neighborhood, one of which was called the "Marble" furnace, and both using the same ore as the old Brush Creek furnace. About the same time two forges were built in the vicinity to produce bar iron from the Brush Creek furnaces. These iron works were all abandoned about 1826, when the rich deposits of the Hanging Rock region were first discovered. In 1816 Aaron Norton built a furnace at Middlebury, near Akron, in Summit county. This furnace was worked with ores of the coal measures until about the year 1840, when it was abandoned. In 1816 also the Mary Ann charcoal furnace was erected in Licking county, about 10 miles northeast of Newark, using the Lower Coal Measure ores of that region.

From this time the manufacture of iron was established in the State, and in the Western Reserve numerous furnaces and forges were in operation in a few years. The ores used by these pioneer furnaces of Northern Ohio were principally the kidney or clay iron-stone of the Lower Coal Measures, derived mainly from accumulations in the valleys, where they had been collected by the action of water and the weathering of the shales of the Coal Measures. Along the edges of the

ridge, which run near to and parallel with the lake, are frequent deposits of bog ores, the deposits from springs, but which nowhere are abundant or rich, containing only from 20 to 30 per cent. of iron. Several furnaces were erected along the lake shore to work these deposits, as at Conneaut, Painesville, Elyria, Vermillion, etc., but the ore was in limited quantities, and becoming exhausted, the furnaces were all abandoned many years ago, and their existence is almost forgotten. The ores in the coal rocks of the northern part of the State were never very abundant, and after the exhaustion of the accumulations in the valleys and streams, they became scarcer and more difficult to obtain, and on this account some furnaces met with indifferent success and were finally abandoned. The shales beneath the coal strata in many places contain quite considerable amount of iron as nodules, and attempts were made to use them, as at the old furnace near Painesville. The nodules in the Erie shales, though quite abundant at this place, were insufficient to sustain successful smelting operations.

The increasing scarcity of the timber necessary for charcoal, in a country rapidly filling up with agricultural settlers, entailed an additional difficulty upon these early iron masters. The capital also required in the operations of iron smelting, and the many risks involved by these pioneers in a country whose resources were but very imperfectly comprehended, rendered the undertaking one peculiarly difficult and hazardous, and too often ended in discouragement and failure. And in fact, it was not until the introduction of the use of mineral fuel and the rich ores of Lake Superior that the iron industry in the northern part of the State was firmly established on a remunerative basis.

A great stimulus was given to the iron industry in the southern part of the State by the discovery of the extensive and rich deposits of the now celebrated Hanging Rock region. The first furnace, called the Union Furnace, was built in 1826, about four miles from the Ohio river, in Lawrence county, near the present town of Hanging Rock, by Messrs. Sparks, Means & Fair, and the first iron was made in 1827. In the same year, 1826, the Franklin furnace was erected in Scioto county, about one-half mile from the Ohio, and 16 miles east of Portsmouth. These early furnaces were of but small capacity, and cold-blast only; they produced from 1 to 2 tons of C. B. iron per day, which was mostly cast directly into pots, kettles, etc. The ores which have made

the iron from this region of so wide a reputation for its unusual purity and strength, are from the Lower Coal Measures, and will be found more fully described elsewhere. Their discovery induced further explorations, and in the course of 15 or 20 years we find the industry spreading in Scioto, Lawrence, Jackson and Vinton counties, in Ohio, and the neighboring region of Kentucky. This region, which in 1825 was almost an unknown wilderness, and though even at the present time but sparsely settled, in 1869 was represented in Ohio alone by 38 charcoal furnaces, producing 90,000 tons, and 5 bituminous coal furnaces producing 16,000 tons, or a total of 106,000 tons.

The Early Charcoal Blast Furnaces of Ohio, with the Date of Erection, Location, Builders, Date of Abandonment, etc.

When built.	Name and Location.	Builders or Owners.	Abandoned.
1808	Yellow Creek Furnace, Mahoning Co	Clendenin, McKay & Montgomery	......
1809	Mosquito Creek Forge, Niles, Trumbull Co	James Heaton	1845
1811	Brush Creek Furnace, Adams Co	......	1826
1812	Mosquito Creek Furnace, Niles, Trumbull Co	James Heaton	1857
1813	Yellow Creek Falls Furnace, Mahoning Co	Daniel Eaton & Sons	1833
1816	Middlebury Furnace, Summit Co	Aaron Norton	1842
1816	Brush Creek Furnace, Adams Co	......	1826
1816	Marble Furnace, Adams Co	......	1826
1816	Mary Ann Furnace, Licking Co	Owned by Dille B. Moore	......
1816	Little Cuyahoga Forge	Asaph Whittlesey	1850
1824	Geauga Furnace, Painsville	Used Bog ore	......
1825	Concord Furnace, Concord, Lake Co	Burned down	......
1825	Railroad Furnace, Perry, Cuyahoga Co	Thorndyke & Drury	1833
1825	Arcole Furnace, Madison, Lake Co	Root & Wheeler (Bog ore)	1851
1826	Union Furnace, Lawrence Co	Sparks, Means & Fair	1854
1826	Franklin Furnace, Franklin P. O., Scioto Co	James F. & Oran B. Gould	......
1828	Junior Furnace, Junior P. O., Scioto Co	Gliddon, Murfin & Co	......
1830	Fairfield Furnace, Fairfield, Tuscarawas Co	Owned by Zoar Community	......
1830	Tuscarawas Furnace, Fairfield, Tuscarawas Co	Christmas Hazlitt & Co,	1846
1832	Arcole Furnace, Madison, Lake Co	Wilkeson & Co. (Bog ore)	1851
1832	Clyde Furnace, Madison, Lake Co	Clyde Co	1838
1832	Elyria Furnace, Elyria, Lorain Co	Herman Ely (Bog ore)	1835
1832	Conneaut Furnace, Conneaut, Ashtabula Co	Bog ore	......
1832	Elyria Forge, Elyria, Lorain Co	Norton & Barnum	......
1834	Dover Furnace, Dover, Cuyahoga Co	Cuyahoga Steam Fur. Co. (Bog ore)	......
1834	Vermillion Furnace, Florence, Huron Co	Geauga Iron Co. (Bog ore)	1840
1835	Mill Creek Furnace, Youngstown, Mahoning Co	Owned by Dan. Grier	1850
1835	Middleburgh Furnace, Berea, Cuyahoga Co	D. Griffiths & Co	1850
1836	La Grange Furnace, Ironton, Lawrence Co	Ohio Iron and Coal Co	1856
1840	Akron Furnace, Akron, Summit Co	Ford, Tod & Rhodes	1855
1847	Empire Furnace, Scioto Co	Gliddin, Murfin & Co	1870
1847	Dresden Furnace, near Zanesville, Muskingum Co	Spaulding & Co	1850
1852	Hocking Furnace, near Logan, Hocking Co	Hocking Iron Co	......
1853	Harrison Furnace, Sciotoville, Scioto Co	H. Spellman & Co	......
1854	Big Sand Furnace, Raccoon Cr., Athens Co	Big Sand Iron Co	......
1854	Tilden Furnace, Vermillion, Huron Co	Owned by Dr. Tilden	......
1855	Five Mile Furnace, near Logan, Hocking Co	Five Mile Furnace Co	......
1856	Oak Ridge Furnace, Symmes Cr., Lawrence Co	......	......
1856	Pioneer Furnace, near Ironton, Lawrence Co	Ormsby, Colvin & Reed	......
1856	Diamond Furnace, near Jackson, Jackson Co	Gralton, Hoffman & Co	......
1857	Young America Furnace, Jackson, Jackson Co	Powell, Oakes & Co	......
1857	Meander Furnace, Austintown, Mahoning Co	Ormond Smith, Porter & Co	......
1858	Zaleski Furnace, Zaleski, Vinton Co	Zaleski Iron Co. (has used coal)	1872
......	Hartford Furnace, Mahoning Co	......	......
......	Dillon Furnace, near Zanesville, Muskingum Co	Chr. Buckingham	1850
......	Tallmadge Furnace, Tallmadge, Summit Co	......	1835
......	Zoar Furnace, Zoar, Tuscarawas Co	Zoar Community	......

As the record of the trials and triumphs of these pioneers in the iron industry of the State must be of interest, and as many of the old establishments are already or will soon be out of memory, the above list is inserted of all the furnaces erected in Ohio, so far as could be ascertained, which have been abandoned. There is added also their date of erection, builders, and the date of their abandonment, wherever possible. Credit should be acknowledged for information concerning the Western Reserve to a paper by Col. Chas. Whittlesey, of Cleveland.

After the establishment of iron smelting in Northern Ohio, the events of the greatest importance in stimulating the industry were the substitution of raw coal in the place of charcoal as the furnace fuel, and the importation and use of the Lake Superior iron ores. The rapidity with which the country was being settled, and cleared of its timber, very early began to embarrass the iron smelters for their supply of charcoal, but more especially the ores, which were never very abundant in this part of the State, became more and more difficult to obtain, and thus some were obliged to discontinue, and others, drawing their ores from a distance, maintained a precarious existence for some time longer. The introduction of the use of raw coal, however, opened up a new and almost inexhaustible supply of fuel, the limits of which, though constantly being increased, are even now not fully realized. The question of priority in the adoption of the use of raw coal in this furnace has been a subject of much discussion, the two places at issue being the Clay Furnace in the Shenango Valley, and the old Mahoning Furnace at Lowellville, Mahoning county. And presuming that some notice of the first use of raw coal may be of interest, the following statement is given on the authority of Messrs. J. M. Edwards and David Himrod, late Manager of Himrod Furnace, at Youngstown, the accuracy of which is generally acknowledged.

The Clay Furnace, which had been built by Messrs. B. B. Vincent and David Himrod at Clarksville, Mercer county, Pennsylvania, was put in blast during the summer of 1845, and was at first planned for using charcoal. There were difficulties in obtaining charcoal, and Mr. Himrod, seeing no prospects for a certain supply, determined upon trying coke made from the coal of the neighborhood, which is the Sharon coal of Western Pennsylvania, and the equivalent of the now renowned Brier Hill, or Coal No. 1 of Ohio. This coal, whose open-burning character is now well known, makes at best a very indifferent

coke, lacking density and hardness. Mr. Himrod, however, coked it in heaps or ricks, and at first used it in the furnace mixed with charcoal, and finally entirely alone with perfect success, both as regards the working of the furnace and the character of the iron. Soon, however, they were met with an additional trouble, for, the cokers striking, they were obliged either to go out of blast or attempt to use the coal without coking, the latter being determined upon. The raw coal was at first mixed with coke, and at last was used alone. These experiments were watched with the greatest interest by others, and when, by the results of the trial, the suitability of raw coal for use in the furnace was established, this material was soon adopted by other furnaces in the Shenango and adjoining Mahoning Valley. The Clay Furnace was the first furnace in the United States to use bituminous coal in the raw state. In Scotland, however, raw bituminous coal had been used extensively for a number of years (at least since 1828), and in Central England and South Wales probably for a longer time. In Ohio the first iron made with raw coal was produced at the Mahoning Furnace at Lowellville, some 7 miles southeast from Youngstown, about one year after the success of the Clay Furnace, or in August, 1846. This furnace was built in 1845 by Messrs. Wilkes, Wilkinson & Co., and continued to use coal from the old Mt. Nebo mines until their abandonment a few years since. Following the favorable results at the Clay and Mahoning Furnaces with the employment of block coal, other furnaces were erected for its use until it became the basis of the most important iron district in the State, and in 1873 there were nearly fifty furnaces dependent upon it in Northeastern Ohio and Northern Pennsylvania.

These conditions continued in Northern Ohio for some ten years without any great change, excepting the more general employment of the block coal, until 1856, when the first development of the iron ores of Lake Superior opened up a new source from which to obtain iron ores, and to compensate in part for the sparsity of their distribution in this part of the State. Though the importance of the Lake Superior ores was acknowledged in 1845 by the formation of the Jackson Company, it was not until 1856 that any regular shipments were made. However, a cargo is said to have been sent to the Clay Furnace in 1854, and Mr. Himrod states that the first iron was made from them in 1855. Although there was some unaccountable prejudice against their use at

first, the trial at the Clay Furnace with the native ores mixed, or the Lake Superior ores alone, demonstrated fully their great value. Gradually becoming more generally employed in Northern Ohio, they have now replaced the use of the native ores almost entirely; the latter, obtained in small quantities, are employed only by some few furnaces in small proportions. Over the rest of the State the Lake Superior ores are now largely employed, as at Steubenville, Wheeling, Columbus, Zanesville, etc., their higher cost than the native ores being compensated by their much larger percentage of iron, purity and improvement in the character of the iron produced. Excepting the iron districts of the Tuscarawas Valley, Hocking Valley, and of the Hanging Rock region in Southern Ohio, the Lake Superior ores are now the main dependence of the iron manufacture in the State, with the addition that on the Ohio River and in Central Ohio assistance is derived to some extent from the Missouri ores, which are similar in character. The advance in the use of the Lake Superior ores may be best comprehended by inspecting the shipments from the Lake Superior ports, of which the greater proportion passes through Cleveland, Western Pennsylvania and Ohio being the chief consumers. Thus the first shipment in 1856 was represented by but 7,000 tons, while in 1870 the shipments were 856,471 tons, and a total since 1856 of 3,771,939 tons, and 25 years later the output of the Lake Superior mines, in 1881, was 2,336,335 gross tons, and probably 3,000,000 tons in 1882.

For convenience in the study of the present iron industry of the State, the various points of manufacture may be separated into regions which, though somewhat arbitrary in their division, individually present such peculiarities of ore, fuel, or position as will warrant their separate consideration.

These regions may be enumerated as follows:

1. Northern Ohio, or the region of the Mahoning Valley, which is distinguished by the use of the celebrated Brier Hill or block coal in the raw state, and the almost exclusive employment of the Lake Superior iron ores. The chief points of manufacture in this region are at Cleveland and vicinity, Akron, and in the valley of the Mahoning River, from Warren, Niles, Youngstown, etc., to the Pennsylvania line. Though not forming part of the view of the Ohio iron industry, mention should properly be made here of the manufacture in the adjoining region of the Shenango Valley, in Pennsylvania, at

Sharon, Middlesex, etc., where conditions precisely similar to those of the Mahoning Valley in Ohio, are the basis of an industry of almost equal importance.

2. The Tuscarawas region, at present represented by but two furnaces in blast.

3. The River region, or region of Steubenville and environs of Wheeling, where the fuel used is coke, and the ores Lake Superior and Missouri. In this division are included the various establishments at Leetonia, Columbiana county, Irondale, Steubenville, Mingo, Martin's Ferry and Bellaire. But as a slight exception to the generalization of the materials of this region, at Leetonia there is used some little native ore and no Missouri ore, and a certain proportion of raw coal in addition to the coke.

4. Central Ohio or Hocking Valley region, where the fuel is raw coal from the Hocking Valley, with some admixture of coke and the ores of Lake Superior and Missouri with about one-half native coal measure ores.

5. The Hanging Rock region of Southern Ohio. The ores are the celebrated hydrated and carbonated ores of the Coal Measures, and the fuel charcoal, coke and raw coal. This region comprises some forty-two furnaces in blast, and some in course of erection, in the counties of Vinton, Jackson, Gallia, Scioto and Lawrence. At Jackson, Ironton, etc., the use of raw coal has been successful for several years past, and at Ironton quite a considerable quantity of Missouri ore is now imported.

6. In the sixth region we may include the isolated points of manufacture in the northwestern part of the State, where the Lake Superior ores are smelted with charcoal, as at Antwerp and Cecil, Paulding county. This region is now of little importance, as possibly before this appears in print, these charcoal furnaces will all be abandoned, but it may confidently be expected that there will rise in their stead, at various points on the Lake Shore, where railroad communication is direct with the coal fields, other establishments using the Lake Superior ores, and raw coal or coke from the rich deposits of the eastern part of the State. Thus at Toledo, Sandusky, Elyria, or Black River, etc., the railroads to the coal fields and the excellent harbors present most excellent facilities for important industries. These same remarks apply with equal force to the future prospects of such towns as Painesville, Ash-

tabula, etc., whose good harborage on the lake and railroad communication directly with the coal fields at the south, present most powerful inducement for successful iron establishments.

The present state of the iron industry will be well shown by the following table, compiled as carefully as possible, and showing the character and location of the furnaces in the State, arranged by districts and counties. The table is complete up to 1882, though it includes some furnaces now abandoned, and many not in blast at present. The ores used are taken from the statements of the furnaces made to the Census Agent, when their production was taken for the Tenth Census. Every care has been taken to secure a careful statement. Copies of this table were sent to parties interested in iron manufacture in the different regions, for correction up to date, and all omissions and mistakes so discovered, corrected.

Following this table, a discussion of the principal features of each district will give a review of the present state of the iron industry of Ohio.

TABLE SHOWING THE LOCATIONS AND CHARACTER OF FURNACES IN OHIO.

MAHONING VALLEY DISTRICT.

Place.	County.	Name of Works.	Owners.	Number of stacks.	Date of erection—First furnace.	Ores Used.	Fuel Used.	Dimensions.
Brier Hill	Mahoning	Brier Hill Iron & Coal Co.	Brier Hill Iron & C. Co.	4	1846	Lake Superior	Coal and coke	66x14½, 80x18, [45x10½, 57x17½,
Youngstown	"	Phoenix & Falcon Furnaces	Brown, Bonnel & Co.	2	1854	"	"	55x12⅔, 50x16
Struther's Station	"	Anna Furnace	" "	1	1869	"	"	74½x16
Youngstown	"	Himrod Furnace	Himrod Furnace Co.	2	1859	Lawrence Co., Pa., Columbiana Co., O., and Lake Superior	Coke	70x15, 70x17
Youngstown	"	Hannah "	Mahoning Valley I. Co.	1	1880	Lake Superior	Coal and coke	65x16
Brier Hill	"	Eagle Furnace	Eagle Furnace Co	1	1846	"	"	51x14
Hazelton	"	Hazelton Fur.	Andrews' Bros. & Co.	2	1867	Lake Sup'r & blackband (nat.)	"	75x18, 56x13½
Lowellville	"	Mary Furnace	Ohio Iron & Steel Co	1	1845	Lake Superior	"	75x15½
Girard	Trumbull	Girard "	Girard Iron Co.	1	1866	Lake Suprior and New York	"	66x16
Hubbard	"	Hubbard Fur.	Andrews & Hitchcock	2	1867	Lake, New York and native	"	60x16, 75x16¾
Niles	"	Thomas Fur.	Thomas Iron Co.	1	1870	Mineral Ridge blackband, and Lake Superior	"	14x55
Newburg	Cuyahoga	Newburg Fur.	Cleveland Roll. Mill Co.	2	1864	Lake Superior	"	60x16, 60x16½
Cleveland	"	River Furnaces	" "	2	1869	"	"	70x16, 70x16
Cleveland	"	Central Furnace	" "	1	1882	"	"	75x20
Newburg	"	Emma "	Newburg Furnace Co.	1	1872	"	"	16x66

TUSCARAWAS VALLEY DISTRICT.

Place.	County.	Name of Works.	Owners.	Number of stacks.	Date of erection—First furnace.	Ores Used.	Fuel Used.	Dimensions.
Massillon	Stark	Volcano Fur.	Volcano Furnace Co.	1	1855	Native blackband	Coal and coke	44x14
Canal Dover	Tuscarawas	Dover Furnace	Penn Iron & Coal Co	1	1878	Native blackband and Lake S.	"	65x16

STEUBENVILLE OR RIVER DISTRICT.

Place.	County.	Name of Works.	Owners.	Number of stacks.	Date of erection—First furnace.	Ores Used.	Fuel Used.	Dimensions.
Leetonia	Columbiana	Cherry Val. Fur.	Cherry Valley Iron Wks.	2	1867	Native and Lake	Coke and coal	75x16, 55x14
Leetonia	"	Grafton Fur's	Grafton Iron Co	2	1866	Lake Superior	Coke	55x13, 55x16
Steubenville	Jefferson	Jefferson I. Wks.	Jefferson Iron Works	2	1863	Missouri and Lake Superior	"	56x13
Steubenville	"	Steubenv. Fur.	Steubenville F. & I. Co.	1	1872	Lake Superior	"	60x16
Mingo Junction	"	Mingo Furnaces	Junction Iron Co.	2	1871	Lake Superior and Missouri	"	60x14, 60x16½
Martin's Ferry	Belmont	Benwood "	Benwood Iron Works, Wheeling, W. Va	1	1865	Lake Superior	"	51x14
Bellaire	"	Bellaire "	Bellaire Nail Works	1	1873	Lake and Missouri	"	65x14

Hocking Valley District.

Place.	County.	Name of Works.	Owners.	Number of stacks.	Date of erection—First furnace.	Ores used.	Fuel used.	Dimensions.
Gore	Perry	Baird Furnace	Baird Iron Co	1	1874–5	Native limestone	Coal and coke	44x11½
New Straitsville	"	Bessie "	Col. & Hock. C. & I. Co	1	1877–8	Native limestone with ¼ Lake	"	60x14
Shawnee	"	Mollie "	Standard C. & I. Co	1	1877	Lake and Native	"	50x14½
Moxahala	"	Moxahala Fur	Moxahala Iron Co	1	1877–8	" "	"	55½x15
Shawnee	"	Fannie Furnace	Licking Iron Co	2	1874–5	Coal, lime, and blackband iron ore are found near the furn's	"	50x12, 50x13
Shawnee	"	XX Furnace	Standard C. & I. Co	1	1876–7	Lake and Native	"	50x14
Greendale	Hocking	Crafts Furnace.	Col. & Hock. C. & I. Co	1	1879	Native limestone and Lake	"	58x15
Orbiston	"	Helen "	Standard C. & I. Co	1	1877	Lake and Native	"	52x15
Monday	"	Lee "	" "	1	1877–8	" "	"	52½x14
Gore	"	Gore "	Col. & Hock. C. & I. Co	1	1876	Baird or Hanging Rock limestone with 1-5 Lake	Coal	47x12⅔
Winona P. O	"	Winona "	" "	1	1878	Native, Lake and Mill cinder	"	50x12½
Buchtel	Athens	Akron "	" "	1	1872	Native	"	60x16
Floodwood	"	Buchtel "	Standard C. & I. Co	2	bldg.	Lake and Native	"	60x16 each
Columbus	Franklin	Franklin "	Franklin Iron Works Co	1	1873	" "	Coal and coke	62x17
Zanesville	Muskingum	Zanesville "	Ohio Iron Co	1	1870	" "	"	65x17

Hanging Rock District.

Place.	County.	Name of Works.	Owners.	Number of stacks.	Date of erection—First furnace.	Ores used.	Fuel used.	Dimensions.
Union Fr. P. O	Hocking	Union Furnace	B. C. & R. D. McManigal	1	1853	Native	Charcoal	32x10
Logan	"	Logan "	Logan Iron Co	1	1852	"	"	29x9
Oreton	Vinton	Eagle "	Eagle Iron Co	1	1852	"	"	32⅔x11
Hamden Junct'n P.O	"	Hamden "	Damarin & Co	1	1854	Limestone	"	34x11
Richland	"	Richland "	Richland Furnace Co	1	1854	Native	"	40x10½
Berlin Cross-roads	Jackson	Buckeye "	Buckeye "	1	1851	Red limestone	"	40½x10
Jackson	"	Cornelia "	Cornelia "	1	1853	Local limestone	"	37x10½
Oak Hill	"	Jefferson "	Jefferson "	1	1854	Limestone	"	40x11½
Keystone Fr.	"	Keystone "	Bundy Iron & Coal Co	1	1849	Native	"	36x10½
Berlin Cross-roads	"	Latrobe "	" "	1	1834	"	"	34x10
Rempel	"	Madison "	Clare, Duduit & Co	1	1854	Native limestone, red	"	37x9½
Monroe Fr, P. O	"	Monroe "	Union Iron Co	1	1856	Native limonite	"	40x12
Bloom Switch	Scioto	Bloom "	J. D. Clare & Co	1	1832	Native	"	33x11
Bloom Switch	"	Howard "	John Campbell	1	1853	"	"	36x10⅔
Scioto Fr. Station	"	Scioto "	L. C. Robinson	1	1844	"	"	32x10¾
Ohio Furnace	"	Ohio "	Means, Kyle & Co	1	1845	"	"	36x11½
Ironton	Lawrence	Buckhorn and Olive Furnaces	Campbell, McGugin & Co	2	1833	"	"	38x10½, 37x10½

Hanging Rock District—Continued.

Place.	County.	Name of Works.	Owners.	Number of stacks.	Date of erection—First furnace.	Ores used.	Fuel used.	Dimensions.
Ironton	Lawrence	Centre Furnace.	W. D. Kelley & Sons	1	1837	Native limestone	Charcoal	40x10½, 43x11
"	"	Etna and Vesuvius Furnaces.	Etna Iron Works	2	1832	Native	"	32x10, 32x9
"	"	Hecla Furnace	Hecla I. & M. Co	1	1833	"	"	32½x11
"	"	Lawrence Fur.	Lawrence Furnace Co	1	1834	"	"	34x10
"	"	Mt. Vernon Fur.	H. Campbell & Sons	1	1833	Native Hematite	"	32x10
Petersburg	"	Monitor Fur	Car-wheel Iron Co	1	1868	Native and West Virginia	"	35x9½
Hanging Rock	"	Pine Grove Fur.	Means, Kyle & Co	1	1829	Native	"	36x12
Gallia Fr. P. O.	Gallia	Gallia Furnace.	Norton, Campbell & Co.	1	1847	"	"	36x10
Vinton Station	Vinton	Vinton "	Vinton Coal & Iron Co.	1	1854	"	Coal	50x11
Wellston	Jackson	Eliza "	Eliza Coal & Iron Co	1	1877	" (block and lime)	"	46x12
"	"	Milton "	Milton Fur. & Coal Co.	1	1873–4	Hanging Rock limestone	"	60x13¾
"	"	Wellston Furn's	Wellston Coal & Iron Co	1	1874–5	4-5 Native with 1-5 Lake	"	52x13
Jackson	"	Fulton Furnace	Globe Iron Co	1	1868	Native	"	50x11¾
"	"	Huron "	Huron Iron Co	1	1875	Native	"	49x13
"	"	Star "	Star Furnace Co	1	1866	Native	Coal and coke.	54x14
"	"	Tropic "	Tropic Furnace Co	1	1872–3	Native and Lake	"	47x11½
Ironton	Lawrence	Belfont Furn's.	Belfont Iron Works	1	1868	Native and Missouri	Coke and coal.	66x16
"	"	Alice & Blanch Furnaces	Etna Iron Works	2	1875	Native	"	86x18, 86x18
"	"	Maggie Furnace	N. Y. & Ohio I. & St. Co.	1	1873–4	"	Coke	58x16
"	"	Sarah "	H. Campbell & Sons	1	1877	Native Hematite	Coke and coal.	50x14
Hanging Rock	"		Means, Kyle & Co	1	bldg.		Coke	65x16
Washington Fr.	"	Washington Fur	Union Iron Co	1	1853	Native		50x13

Additional Furnaces—Charcoal.

Place.	County.	Name of Works.	Owners.	Number of stacks.	Date of erection—First furnace.	Ores used.	Fuel used.	Dimensions.
Ironville, Toledo	Lucas	Manhattan Fur.	Toledo Iron Co	1	1866	Lake	Charcoal	40x9
Antwerp	Paulding	Maumee Fur	Fitzsimons Furnace Co.	1	1865	"	"	42x8½
Cecil	"	Paulding Fur	Paulding Iron Co	1	1865	"	"	42x10

Note.—The Grant Furnace at Ironton has been torn down within a year, and is hence omitted from this table.

The Mahoning Valley District.

This includes the works situated at or near Youngstown and Cleveland, in Mahoning, Trumbull and Cuyahoga counties. These works use the ores from the Lake Superior districts almost exclusively, but also some native ore. The blackband found in Stark, Mahoning and Tuscarawas counties, after being roasted at the mines, is shipped to several furnaces at Niles, Brier Hill and Youngstown. It is used with some Lake and Canada ores, to make a so-called "American Scotch" pig-iron. The "kidney" ores from Columbiana county are also a considerable source of supply; these ores, occurring in rather extensive deposits, as bars or gravel banks, along the Middle Fork of Little Beaver river, are there separated by picking and screening from the associated gravel, and then roasted in heaps or piles with coal slack. The ore thus roasted contains about 45 per cent. of iron on the average. The amount of this ore used is not large compared with the enormous consumption of Lake ores, but its cheapness makes it desirable in a certain proportion, as it can be furnished at Youngstown at from $3.00 to $3.25 per ton, while the Lake ores cost $6.00 to $8.00.

Another available source of cheap ores is the deposit at Wampum, Lawrence Co., Pa., from which considerable ore at $3.00 to $3.50 is sent to Youngstown and vicinity. These ores are soft hydrated hematites, containing 40 to 45 per cent. of iron. The following analysis, furnished through the kindness of one of the furnace companies, illustrates its composition:

"WAMPUM ORE."

Sesquioxide of iron	64.29
Alumina	5.90
Silica	13.24
Oxide manganese	1.52
Lime	.40
Magnesia	.47
Phosphoric acid	.48
Carbonic acid and water	13.98
Total	100.28

J. K. SHINN, *Chemist.*

The following is a partial analysis of the New Lisbon kidney ore. The analysis was made of a single "kidney," taken from the roasted pile, and represents possibly a rather better than average specimen:

Sesquioxide of iron	69.70
Silica	16.58
Alumina	5.20
Phosphoric acid	0.50
Metallic iron	48.79
Phosphorus	0.22

LORD, *Chemist.*

The blackband ores mined with the coal at Mineral Ridge contain enough bituminous matter to burn alone, and are roasted in heaps at the mines. The following is Prof. Wormley's analysis of unroasted ore from Mineral Ridge:

Volatile matter	30.50
Silicious matter	11.84
Carbonate of iron	43.26
Oxide of iron	8.94
Alumina	Trace.
Oxide manganese	1.00
Phosphate of lime	Trace.
Carbonate of lime	1.87
Carbonate of magnesia	2.03
Sulphur	0.18
Total	99.62
Metallic iron	27.12

The extremely small amount of phosphorus in this sample is exceptional. This ore after being roasted would contain about as follows:

Sesquioxide of iron	72.0
Silicious matter	24.0
Oxide manganese, Lime, Magnesia	4.0
Total	100.0
Metallic iron	54.4

This is about the per cent. of iron claimed by the sellers. This ore brought during the census year from $5.25 to $5.50 at the furnaces. It is used in mixtures, to give a very soft and tough foundry iron, being used with Lake Superior hematites or New York magnetites. As already stated, this is especially advertised as "American Scotch Pig."

Of the vast quantities of Lake Superior ores used in this district it need only be said, that they form the main supply of the furnaces, especially at Cleveland and Youngstown, their high grade and pure character compensating for their higher prices. To show the relative amounts of these ores used during the census year, the following figures, taken from six of the principal works of the Mahoning Valley, and representing the total purchases of ore from June 1879 to June 1880, will be of interest:

	Tons, 2,240 lbs.
Lake Superior and Canada	229,427
Native Ohio ores	14,802
Pennsylvania and New York ores	28,219

The list includes the works at Cleveland. Leaving these out, the Youngstown furnaces would show a larger percentage of Native ore, but would still leave the Lake ores far in excess.

The Lake Superior mines being distinct organizations, and not connected with the smelting works, the price of ore is rather variable, and also the ore supply of the different furnaces of this district will vary in quality with the fluctuating value of the different Lake ores. This is especially true since the rapid development of the Marquette and Mennomonie regions has sent into the market very large amounts of second grade ore at a lower rate, somewhat lower in iron and higher in phosphorus and sulphur.

To the above rule there are some exceptions, some of the furnace companies being owners of mines in the lake region, and depending for a partial supply at least upon their own properties.

The fuel used in this district is the Brier Hill block coal and Connellsville coke. The use of coke has steadily increased, owing to the continued decrease in its price, until at present (1883) the furnaces of this district have almost entirely given up the use of raw coal, even in admixture with coke. A letter from a prominent iron smelter relative to this matter, received October 10, 1883, says that "most of the furnaces of the Mahoning Valley use no block coal whatever, running entirely on Connellsville coke, and none use block coal entirely."

The block coal is a dry, open-burning coal, which is discussed fully in the report on coals.

Where coal is mixed with coke it constitutes one-third to one-fourth of the fuel used.

To illustrate the working of these fuels with Lake ore, the following summary of a week's run of a large furnace using Lake ore and making Bessemer pig-iron, may be of value:

CHARGES.

	Tons, 2,000 lbs.
Ore	680.78
Steel scale	18.12
Limestone	232.71
Coke	430.50
Coal	172.02
Iron produced	448.93

The furnace had not been in blast very long. The iron produced was No. 1 foundry, for use in the converter in making steel.

A furnace company using native ore and coke has kindly allowed the following figures to be taken from their charging books:

SIX DAYS' RUN OF FURNACE.—NUMBER CHARGES, 554.

	Tons, 2,000 lbs.
Lake ore and cinder	286.69
"Wampum ore"	286.69
Limestone	291.91
Coke	515.77
Iron made	284.

Again as still another example, the following charge may be taken, representing also a week's run:

	Tons, 2,000 lbs.
Lake ores	428.23
Limestone	180.60
Coal	77.40
Coke	338.49
Iron made	254.3

These figures may be taken as fairly representing the working of the furnaces of the region. The pure Lake ores enable them to use low amounts of coke to the ton of iron, as the amount of fuel required is rapidly augmented when the sterile material in the ore increases. This fact often not considered is the explanation of the large amounts of fuel used in regions of the State smelting low grade ores.

The Mahoning Valley district, including Cleveland, is at present the principal iron producing region of the State, its total product far exceeding that of the other districts. The establishments are large and

complete, though the total number is less considerably than in some of the other districts. The production capacity of the fifteen establishments, given in the tabular statement, is about 586,000 tons of iron a year, and omitting the Cleveland furnaces the production capacity of the Mahoning and Trumbull county furnaces (18 stacks) is 393,000 tons of 2,000 lbs. The actual production of pig-iron in these counties for 1881 was, according to the official reports of the Iron and Steel Association, 245,737 net tons.

The industry, however, does not belong so peculiarly to Ohio as that of the other districts, the ores and fuel being so largely derived from other States, and the enormous industry owing its growth largely to the advantages the location offers as a meeting ground for the Lake ores and the Pennsylvania coke. The furnaces, in their complete equipment and large capacity, resemble the establishments of Pennsylvania and the east, and differ radically from the smaller works in the other districts where the native ores are a prominent factor in the working, and which have therefore a more distinctive character in their arrangement to meet local contingencies.

In regard to economy of working and fuel consumption, the furnaces of this district will compare favorably with any. The figures above given show a coke consumption of only 1.19 to 1.33 tons to the ton of pig-iron made, assuming, as is undoubtedly correct, that the raw coal only contributes the coke it will furnish as real fuel in the furnace. The gaseous matter is all expelled at too low a temperature to have any influence as a reducing agent, and probably only acts as a heat consumer instead of producer, as some heat is required to expel this volatile carbonaceous matter.

A coke production of 60 per cent. in the Brier Hill coal is also assumed.

Taking Bell's figures (Chemical Phenomena of Iron Smelting, p. 15) for Clarence Works, as the best English working at that date, 1.12 tons coke for 1 ton iron is given, of course using a leaner ore than in the case of the furnace from which the above figures were taken, which used an exceptionally rich mixture. As the course of iron smelting has been continually toward larger production per ton of coal, the introduction of better stoves and the more careful regulation of flux and ore mixture will probably yet reduce the above already low figures.

The details of the furnaces and machinery in this district, together

with a discussion of the ores and fluxes, will appear elsewhere in the part of this report treating of furnaces and modes of smelting.

The Tuscarawas Region.

This region, as is shown by the table of furnaces, is at present represented by but two furnaces in operation, one at Massillon and one at Canal Dover.

The ore of the region is the famous blackband deposit, the fuel the Massillon coal, which is used raw in the furnace.

The ore forms one of the most remarkable deposits of the Ohio Coal Measures; it has been known and used in this district for over 45 years, and large developments of it have been made. The limits and extent of the deposit will be found defined and discussed in the report on iron ores.

The beneficial results which have attended smelting the hard crystalline ores of Lake Superior, etc., with the argillaceous ores of the Coal Measures, would render the importation and mixture of these ores with the blackband a very important addition to the resources of the region.

The blackband is a black bituminous shale, containing so much iron as to make it valuable as an ore. In appearance it resembles the ordinary black shales of the Coal Measures so closely, that one not familiar with its peculiar features would be very easily misled as regards its true character. Its specific gravity, however, is comparatively high. In weathering the blackband changes to a grayish color, and breaks up into thin laminae or scales, which resemble most anything rather than an ore of iron. By testing their weight, however, their great specific gravity will suggest their ferriferous character.

The ore is subject to great variations, both in thickness and quality, and, though its average thickness may be stated as about 10 feet, it is sometimes cut out entirely by sandstone, but sometimes it attains the thickness of 16 feet. Not unfrequently it passes into a bituminous shale, valueless as an ore, and at other times becoming thin, is represented only by an accumulation of kidney ore. In some localities it is associated with a calcareous iron ore, whose position is immediately above the blackband. This calcareous ore, which elsewhere is a non-ferriferous limestone, has been extensively mined in eastern Tuscarawas county, as on the property of the old Zoar Furnace, in Fairfield town-

ship, and is known as the "Mountain ore." The blackband iron ore, which is the basis of the celebrated Scotch iron region, resembles the blackband of the Tuscarawas Valley. The Scotch blackband ore seams are also limited in their extent, and are rarely continuous over any very large area without change of composition. Though the Scotch ores are sometimes found 5 feet or more in thickness, they average only from 6 to 15 inches. In richness, however, the Tuscarawas blackband is inferior to the Scotch ores, as while the former yields about 25 per cent., the latter contain 30 to 40 per cent. of metallic iron in the raw state.* The Tuscarawas blackband is also less rich than the blackband of the Mahoning Valley, before alluded to. The following analyses of the ore used at the Dover Furnace will show the composition of the ore, both in its raw and calcined state:

	Raw.	Calcined.
Specific gravity	2.321	3.411
Carbonic acid	15.00	....
Water	.. ..	0.25
Volatile matter	21.10	....
Silicious matter	26.22	17.02
Iron peroxide	8.79	75.00
Iron protoxide	23.02	....
Alumina	0.70	0.60
Manganese	1.70	1.65
Lime	1.70	2.80
Magnesia	0.88	1.48
Phosphoric acid	0.492	0.773
Sulphur	0.11	trace.
	99.712	99.573
Metallic iron	24.06	52.5

The blackband has been mined chiefly by stripping the outcrop and quarrying on the face of the stratum. A wall of the ore thus exposed, 10 or more feet in height, and several hundred feet long, is a sight of no little interest. The ore has thus been very generally worked by simple quarrying, though now considerable is obtained by a regular system of mining by drifts and galleries, as in working a coal seam. The great thickness of the bed renders this method easily applicable, and in this manner the ore may be mined for 75 cents per ton, one man

* Bauerman's Metallurgy of Iron.

easily producing 3 tons per day. When mined, the ore is usually calcined on the spot in heaps, and the burnt ore then transported to the smelting furnaces. In building the piles, the ore is placed on its edge, so as to facilitate the operation. Considerable quantities of fuel have been heretofore mixed with the ore in the heaps, though it seems that there is sufficient carbonaceous matter in the blackband itself to produce the calcination when once the combustion has been started. The fuel that has been used for this purpose is the underlying coal No. 7, which contains considerable sulphur, and hence is disadvantageous, as it contaminates the ore with the ash and increases the amount of foreign matter. The fact of the coal thus adding impurities to the ore, which affect the quality of the iron, is becoming understood, and less is now being used, though any fuel beyond the amount required to start the pile seems hardly necessary. The ore is so easily reducible and fusible, that notwithstanding the care which may be taken in calcining it, large masses become cemented together in the hottest parts of the pile, and if the heat has been too high, these masses or "loups" are so hard as to require severe labor to remove and break them up. In calcining, the ore loses considerable as fine dust, which is separated by screening, but it becomes enriched by the expulsion of the volatile matter from an ore of 25 per cent. to one containing 50 per cent. of metallic iron. At the Massillon and Dover furnaces there are consumed about 2 tons to 2½ tons of ore to make a ton of pig-iron. The value of this ore, of course, varies, owing to different circumstances, but in 1879–80 it was worth in the neighborhood of $2.50 to $2.75 at the furnaces. Beside the blackband ore some little "Mountain ore," the calcareous ore overlying the blackband in places, is used, but the quantity is not large. It is of but local importance, and has been obtained chiefly in the eastern part of Tuscarawas county, in Fairfield township. The ore is subjected to calcination in heap, as is usually done with ores of its class. As an ore it is highly valued. Nodular clay ironstone, "kidney" or "shell" ore is obtained in some quantity, but the supply is derived from surface pickings from the accumulation in the valleys and runs, where they have been weathered and accumulated from the shales which bear them.

Horizons specially rich in these ores in the Coal Measures have already been referred to, as the shales over Coal No. 5, the Mineral Point or Newberry seam at Mineral Point and other places in Tus-

carawas county, and in some localities the horizon of the blackband. But nowhere, however, as in the other parts of Ohio, are the kidneys in sufficient abundance in the shales to pay for their extraction by mining. Within the last two or three years the Lake Superior ores have been used with the native ores at Massillon. These Lake ores were tried at Massillon many years ago, but from about 1870 till recently were not used in this district.

Several years ago the Dover Furnace used largely coke made from seam No. 5, the Newberry or Tunnel seam, from the Tunnel mines in Sandy township. This coal contains considerable sulphur, does not make a very good coke, and its use is entirely superseded by the Massillon coal which now is the fuel used by the furnaces at Dover and Massillon. The Massillon coal has been mined principally within a distance of 10 or 15 miles northwest and west from Massillon. The Massillon coal, or Coal No. 1, is the lowest coal in the series, and the equivalent of the block coal of the Mahoning Valley, which it resembles very closely. The Massillon coal is equally pure, but it is not so dry a coal, and contains a larger proportion of bituminous matter. It is nevertheless an excellent open-burning coal, and, though it is said that a coke of fair quality can be made from it, its use raw in the furnaces has been so successful that it is used altogether in the raw state. The following analysis, made by Prof. Wormley, will illustrate its composition:

WILLOW BANK.

Specific gravity	1.247
Moisture	6 95
Volatile combustible matter	32.38
Fixed carbon	57.49
Sulphur	....
Ash	1.80
	100.
Sulphur	0.79

The coal in 1870–73 was valued at the mines at $2.50 to $2.75 or $3.00 per ton at Massillon. This coal also resembles very closely the splint coal of Scotland, which is the fuel used in smelting the Scotch blackbands. Before the introduction of the hot-blast the Scotch coal was always coked, but now it is used altogether in the raw state.

The furnaces of the Tuscarawas region use the hot-blast and require from 3.5 to 4.00 tons of coal per ton of iron. This amount ot

fuel is very excessive, and there is no possible doubt that by improvements in the furnaces, and better utilization of the waste gases, etc., the consumption might be reduced.

Considering that the coal yields but 60 per cent. of fixed carbon or coke (the volatile matter probably is all expelled before it can have much, if any, action of reduction), the fuel consumption is equivalent to 2 to $2\frac{1}{2}$ tons of coke per ton of iron.

The Connellsville coke, as in the Mahoning Valley, will probably acquire greater importance as a fuel in this district. The low prices at which this remarkable fuel is at present furnished is leading to its greater and greater use. The Tuscarawas Valley region has fallen behind the other districts of the State in rate of development. At different times extensive attempts have been made to develop it, but thus far with limited success. Large works were started at "Glasgow-Port Washington," two large furnaces, 70 by $17\frac{1}{2}$, being built and finely equipped, intended to smelt the Tuscarawas blackband ores with raw coal and coke, made from the coal found at that point. After a few years the furnaces were sold and removed to Pittsburgh. The lean character of the blackband ores has become more and more apparent, and their smelting as a source of iron to compete with that produced in the Mahoning Valley from the richer Lake ores has been rather an expensive experiment.

The district is at present represented by but the two furnaces above spoken of, which together have an estimated capacity of only about 21,000 tons, and the total production of Stark and Tuscarawas counties for the census year was not over 17,000 tons.

Eastern Ohio, or the Steubenville and Wheeling Region.

The region of the iron manufacture in Ohio which is separated under this division, embraces a number of furnaces in the eastern part of the State on or near the Ohio River, which are removed by considerable distances from each other, but as a group use coke as an almost exclusive fuel. Their geographical position also separates them from the other iron centers of the State. The ores employed are the Missouri and Lake Superior specular and hematites, with, at Leetonia, an admixture of native Coal Measure ores. The establishments thus included are the two blast-furnaces of the Cherry Valley Iron Works, and the two of the Grafton Iron Works, at Leetonia, in Columbiana

county, the two furnaces of the Jefferson Iron Works at Steubenville, the furnace of the Steubenville Furnace and Iron Company, and the two Mingo Furnaces, in Jefferson county, the Benwood Furnace at Martin's Ferry, and the furnace of the Bellaire Nail Works at Bellaire, in Belmont county. The quality of iron principally made by these furnaces is a forge iron for conversion into wrought iron by the puddling process in the rolling-mills; considerable quantities of a higher grade of iron are also obtained specially adapted for foundry purposes.

Beside the blast-furnaces of the region, there are several rolling-mills producing different kinds of merchantable wrought iron, many of the blast-furnaces being run in connection with such works producing the pig-iron for conversion into wrought iron, as at the Cherry Valley Iron Works, the Bellaire Nail Works, and others.

The facilities for transportation in this region are: First, the Ohio River, which is at present almost always navigable as far as Wheeling, and, subject to changes in the level of the river, to Pittsburgh. The Missouri ores are thus directly shipped from St. Louis by boat, and discharged at the works along the river, and markets are rendered cheaply accessible from Pittsburgh to St. Louis, and all points on the waters of the Ohio and Mississippi. Though as a means of communication the river is in certain seasons of the year quite uncertain, the improvements which must sooner or later be made in its navigation, will fix the river in its natural position as the great and cheap highway of the Ohio Valley. Second, the railway systems. In an east and west direction the region is intersected by two great trunk lines, the Pittsburgh, Cincinnati and St. Louis Railway from Pittsburgh, passing through Steubenville, and thence through Newark, Columbus, Cincinnati, etc., and the Baltimore and Ohio Railway from Baltimore, passing through Wheeling, Bellaire, and westward to Newark, Columbus, etc., and to the Lake region at Sandusky. In a north direction communication is had at present from Wheeling through Steubenville, etc., to Pittsburgh, and to Lake Erie at Cleveland, by the C. & P. R. R. By this route the Lake Superior ores are now distributed to the furnaces on the Ohio.

Not included in these systems of communication, Leetonia is on the line of the Pittsburgh, Ft. Wayne and Chicago Railway, which passes east and west through the State, and communication is also had with the region of the Mahoning Valley and Cleveland by the N. Y., P. & O., New Lisbon Branch.

This region of the iron manufacture in Ohio is entirely within the area of the Coal Measures, and in the eastern margin of their development in Ohio, and in an east and west direction nearly in the center of the Allegheny Coal Basin. In the northern part of the region, in Columbiana and Jefferson counties, the coals of the Lower Coal Measures are finely developed, while in southern Jefferson and Belmont the upper series of coals come in, and at Wheeling the great bed of the Upper Coal Measures, Coal No. 8, or the Pittsburgh coal, is magnificently exposed. In a general discussion of the iron manufacture of the Allegheny Coal Basin, this region, from the conditions of ore and fuel and its geographical relations, would be properly included in the group embracing the Pittsburgh region. The ores are the same, and probably can be obtained in the Ohio region as readily and cheaply as at Pittsburgh.

The ores which supply the manufacture in this region are, excepting a small quantity of native ores which are sometimes used, especially at Leetonia, exclusively obtained from other States, namely, the specular ores of Iron Mountain and Pilot Knob, in Missouri; the specular and magnetic of Lake Superior, and occasionally the magnetic ores of Canada. The native ores which are used are the clay ironstones or kidney ores of the Coal Measures. The quite wide distribution of these ores, and the particular accumulations at certain horizons in the Lower Coal Measures are repeatedly referred to, but they are obtained in so small proportions that they are but a very unimportant element in the iron manufacture of the region. In Columbiana county at various places, as at Leetonia, Fredericktown, and the valley of the Beaver, the roof shale of Coal No. 6 is locally impregnated with iron so as to form a blackband iron ore, but it is not used in any of the furnaces. Over Coal No. 4*a* the limestone seam (the "Creek vein" of the Yellow Creek Valley), in Columbiana county, the kidney ore is quite abundant, and is found sometimes in tiers of nodules distributed through 10 or 15 feet of shale. The upper part of the limestone is also in places sometimes a calcareous iron ore, as in the valley of the Beaver. Over Coal No. 6, the Leetonia seam, (the "Strip vein" of the Yellow Creek), there are also found quite considerable quantities of kidney ore in the Yellow Creek Valley.

At Irondale the nodules were so abundantly scattered through the 12 feet of shale overlying the place of the coal, that an attempt was

made to mine for them, but they were not found in paying quantities, and, although they were an excellent ore, the attempt was abandoned. At Collinwood, near Linton, the ore at this horizon was so plenty that large expectations were built upon its utilization, but these expectations have not been realized. Numerous analyses of these Collinwood ores were published in the report of Prof. Newberry, in the Geological Report for 1870, p. 49. Considerable amounts of these kidneys are obtained, especially in Columbiana county—some by stripping the beds, but principally from the gravels of the valleys and creek bottoms where they have accumulated from the degradation of their enclosing stratum; the heavy iron ore remaining while the lighter material was washed away. From what has been said of the occurrence of these ores it is not at all likely that they will be found in quantities sufficient to sustain mining.

Concerning the character of the ores of the Pilot Knob, Iron Mountain, etc., in Missouri, and those from the Lake Superior district, enough has probably already been said when speaking of the general conditions of the manufacture of iron in Ohio, and of the region of the Mahoning Valley. The furnace establishments are organizations entirely separate from the proprietorships of the mines in these other States, and the ores are obtained from these mining companies at a price fixed by contract, and fluctuating with the activity of the market. The contract system is the very general custom, and contracts are usually made in the early part of the winter at so much per ton, delivered at various times during the following year, for the Lake Superior ores at Cleveland, or some port on the Lake, and for Missouri ore, delivered at St. Louis. Hence, it will be seen the proportion of these ores used will depend upon the favorable terms with which contracts can be made with these two ore regions. The proportion used does not vary much, however, from about 50 per cent. of the Missouri ores, and 50 per cent. of the Lake Superior ore. But at Leetonia and Irondale little of the Missouri ores is obtained (probably because of the expense of a trans-shipment at the river), the chief dependence being upon the Lake Superior ores.

Some small quantities of the Canadian magnetites from the region north of Kingston, on Lake Ontario, on the Rideau Canal, etc., have been used in this region, especially at Irondale and Leetonia. The character of these ores is somewhat variable, and they are not desir-

able ores to use in large proportions, because of the impurities which they contain, viz., sulphur and titanium. Most all of them are titaniferous, many of them containing from 10 to 12 per cent. of titanic acid, which is one of the most objectionable substances to contend with in smelting the ores of iron.

The "Clinton ore" of Wayne Co., New York, which is precisely the same in character as the "flax-seed" ore of Dodge county, Wisconsin, and the "Dyestone" ore of Tennessee, has been used at Irondale in some small proportions. The ore contains as a principal impurity, phosphorus, which gives a cold short and hard character to the iron made from it. This, however, is considered as a favorable mixture, especially for the wearing surface of rails, where a particularly hard surface is desired.

The Mingo furnaces, in 1873, used some limonite ores from Kentucky, in the vicinity of Louisville, and from Alabama. The ores are of excellent quality for admixture with the hard crystalline ores of Missouri and Lake Superior, and their more general use in such connection would undoubtedly favor the regular working of the furnace.

In this connection mention might properly be made of a fact which is patent to all rolling-mill proprietors, that the variations in the kind and proportion of materials used in the blast furnace entail a change in the character of the iron. That pig-irons made from different materials entail some differences in the process of puddling and the character of the finished iron is well known. Thus in many cases in the west, and to a greater or less extent in the United States, the rolling-mill proprietor, in purchasing an iron, it may be from the same furnace, is not always postive of its uniformity and consequently of his product. This is a complaint which is very often made of our American pig-iron, wrought-irons and steels, when comparing them with English makes, that they are not *uniform* in quality, while the latter are. A furnace or a rolling-mill which produces constantly an iron of an established and well-known quality, will obtain higher prices than other makers for their product.

The flux which is used in the region is readily obtainable from the numerous limestone strata of the Coal Measures. In Columbiana county are the two limestones which may be associated with the limestone seams of coal. On the Yellow Creek, Steubenville and Mingo the chief source is from the stratum of excellent limestone, the "Fossilifer-

ous limestone," of the barren coal measures, which is so important a feature of the Coal Measures, from Linton to some distance below Steubenville. At Bellaire, Wheeling, etc., there is an inexhaustible supply of limestone in the stratum, immediately overlying Coal No. 8, the Pittsburgh coal, usually about 20 feet thick. Some portions of this are sent up the river and used at Steubenville and Mingo. This is the same stratum from which the furnaces obtain their supply at Pittsburgh. Analyses of these limestones have been made by Dr. Wormley, and appear in the report of the Chemist (Report of 1870).

As has been said, the fuel of this region is almost entirely Connellsville coke. At Leetonia, however, and at Steubenville some coke is made from the Ohio coal, the furnaces of the Cherry Valley Iron Works using almost entirely, coke made in bee hive ovens at the furnace. The Grafton works also have some fifty ovens, and while they purchase a large amount of Connellsville coke, also, when prices of labor and coal are favorable, run on coke made at their works.

As at many other works in the State, mill cinder is largely used in the manufacture of iron at the various works in the Steubenville district. The peculiar character of this material in its relation to smelting will be discussed further on.

The Hocking Valley District.

The iron works designated as belonging to this region comprise those situated in Hocking, Perry and Athens counties. They form a distinctive class of works, using the native ores of the Lower Coal Measures and the famous furnace coals of the Hocking Valley. They are allied to the numerous charcoal furnaces of the Hanging Rock region, representing the application of raw coal to much the same class of ores as the charcoal furnaces smelt with charcoal. The furnaces are mostly of recent date and present peculiarities of working of much interest to the metallurgist. Of late years the Lake Superior ores have been used more and more in mixture with the native ores, these latter having somewhat disappointed the expectation at first entertained as to their richness and purity. The establishment of railroads all through the district has followed its mineral development, and it is now, through the Columbus & Hocking Valley and the Ohio Central Railroad brought well into communication with the railway system of the State. The works of the valley are mostly comprised between Logan, Hocking

county, Floodwood, on the Hocking river, in Athens county, and Moxahala in Perry county, in a triangular space about 15 by 18 miles. Within this district, and connected by a system of branch lines with the Hocking Valley, Muskingum Valley and Ohio Central Roads, lie the furnaces properly belonging to the Hocking Valley district.

The native ores are mined at or near the furnaces, either upon the furnace property, or are brought in by farmers upon whose lands the exposure occurs, and who during such time as they can spare from the ordinary work of their farms, dig ore in small amounts and bring it to the furnaces. The Coal Measure ores, forming beds of from a few inches to some feet in thickness, crop out along the hill-sides over this region. The ore is obtained almost universally by "stripping," which consists in removing the earth and slates from above the bed of ore, by digging out with pick and shovel, or, in some cases, using "scrapers" for the same purpose. This process exposes a shelf or layer of ore which is readily removed by breaking or blasting. The extent to which the hill can be thus worked into will vary with its steepness, but does not often exceed 20 or 30 feet.

When the depth in the hill becomes so great as to render the uncovering of the ore too expensive, the locality is abandoned and a new one worked. "Drifting" for the ore is practiced somewhat, tunnels or entries being run into the hill, and the narrow layer of ore mined out. The extent of these drift mines in the Hocking Valley district is limited; in Lawrence county, however, some furnaces, as the Hecla, near Ironton, have established quite extensive mines; there the hill has been tunnelled for a distance of some hundreds of feet, and the ore removed by a regular long-wall system of mining, miners filling the empty space behind with the refuse gangue accompanying the ore.

At present (1883) this mining in a small way has been largely given up, the ore supplies of the furnaces being derived from the properties owned by the combination known as J. R. Buchtel & Co., the companies being made more independent of the necessarilly uncertain supply furnished by this sort of "farmer mining."

The method of working has led to some curious and sometimes rather disastrous results as to variation in quality of ore. The ores in place are as a rule essentially carbonates of iron, and where drifted for, so as to expose the unaltered ore, present the usual blue or gray appearance of a spathic iron or siderite. These carbonates, however, soon

"weather" or change by the action of the air, rains and frost, to a red, soft, hydrated oxide. These hydrated oxides, containing water in place of carbonic acid, are richer in iron. This, however, would be of but small moment, as by roasting, both ores would be brought to the same condition, were it not for the fact that the associated impurities of the ore are to a certain and sometimes a large extent separated by this same weathering, so that an ore, which at its outcrop on the hill-side may appear pure and rich, may, as the ore is taken out at greater depths, fall off in iron and increase steadily in percentage of phosphorus and silicon. That this has led to serious misjudgment in regard to many of the ore deposits of the Hocking Valley, can not be doubted.

In fact, in several cases where "drifting" for ore was undertaken, the work had to be abandoned, as when the solid ore was reached it became so lean, passing in some cases into little more than a ferruginous limestone. The lime being one of the most easily dissolved of the associates of the iron, the surface and outcrop ores are usually low in it, but the ore in depth is liable to contain much more.

A sample of ore taken from the ore piles at Logan furnace will illustrate this point. The ore was mostly a red or brown limonite or hydrated oxide, and was used for making a charcoal pig of good quality, but as the miners were going deeper into the deposit, they found associated with the red ore an increasing percentage of "white ore," a drab unaltered carbonate. This yielded on analysis:

Silicious matter	6.18
Metallic iron	31.80
Phosphorus	1.84

LORD, *Chemist.*

This extraordinary percentage of phosphorus is not without parallel. A sample of similar blue ore, taken from a large deposit near Moxahala, which had been opened at some expense, and was supposed to be, from analysis made upon the outcrop, of excellent quality, showed:

Iron	37.40
Phosphorus	2.41

This ore tried subsequently in the furnace, yielded a pig-iron which was so brittle that it could be ground to powder in an ordinary mortar, and showed on analysis:

Phosphorus	4.9 per cent.

The ores of the valley, with the exception of one or two standard deposits, are very difficult to obtain correct analysis of, owing to the above stated causes.

The following, not published before, made at the Laboratory of the State University, during the last 3 or 4 years, may be of interest; the samples were in most cases sent to the laboratory by those interested in furnaces, and were intended to represent the deposits fairly:

	1.	2.	3.	4.	5.
Metallic iron	35.37	36.96	30.20	44.65	38.70
Silicious matter	11.58	2.73	15.80	22.15	35.73
Lime	4.47	3.86	2.97	1.12	....
Alumina	1.78	4.82	10.64	9.31	....
Magnesia	1.23	1.87	1.26	0.42	....
Phosphoric acid	0.60	0.83	0.16	0.41	1.55
Sulphur	0.54	0.52	0.15	0.40	0.01
Phosphorus	0.257	0.356	0.07	0.175	0.66

1. Baird ore—Nelsonville. Chemist, Howard.
2. Iron Point ore—Lime and magnesia as carbonates. Chemist, Howard.
3. Baird ore—Bessie Furnace. Chemist, Lord.
4. Roasted Limestone ore—Average sample. Chemist, Lord.
5. New vein of ore 18 in. thick—20 ft. above Zoar limestone. Chemist, Lord.

The native ores of the valley run on the average rather high in silica and phosphorus. This may be illustrated better, perhaps, in the character of the pig-iron than by samples of the ores, as the pig-iron will collect all the phosphorus in the furnace. As the amount of this element furnished by the fuel and flux is very small, the contents in the iron may be, without much error, charged to the ore.

The following are a series of determinations of phosphorus, made on samples of pig-iron manufactured from the ores of the Coal Measures:

	1	2	3	4	5	6	7	8	9	10	11	12
Phosphorus	0.50	0.64	0.60	0.656	0.56	0.495	0.86	0.77	0.997	0.885	0.725	0.627

The numbers 1 to 5 are samples made about 1879, the others later and with, in the last four numbers, some admixture of mill cinder and Lake ores, so the best native ores may be considered as yielding a pig-

iron which will run about 0.6 to 0.7 per cent. of phosphorus, or if only ores from the weathered outcrop be used and carefully selected, the average might run down to about 0.50 per cent. of phosphorus.

If we assume the average yield of the ore at 40 per cent., or $2\frac{1}{2}$ tons of ore to 1 ton of iron, the average per cent. of phosphorus would be about 0.24.

The yield of the ore is best shown by taking the running of a charcoal furnace using only native ore. A run of 12 weeks at such a furnace in Vinton county showed:

Native ore used.. 4,792,410 lbs.
Iron made.. 895.09 tons of 2,266 lbs.

This pig-iron contained on analysis 93 per cent. of metallic iron. Calculating the percentage yielded by this ore, we find 39.4 per cent. metallic iron in the ore.

Figures taken from the charging books of a furnace near Ironton, using the native ores exclusively, show for three consecutive years the following amounts of ore used: 2.58, 2.57 and 2.75 tons of ore. These figures are rather higher than those above given, and show a lower percentage in the ore.

The limestones used as fluxes in the Hocking Valley may be illustrated by the following analyses, made in the University Laboratory at Columbus:

	1.	2.	3.	4.	5.
Silicious matter	5.45	12.1	3.50	4.25	4.60
Carbonate of lime	56.30	86.9	79.01	94.19	80.40
Carbonate of magnesia	32.40	0.8	16.85	1.29	13.80
Oxides, iron and alumina	5.60	0.45	0.50	0.26	1.25
Total	99.75	100.25	99.86	99.99	100.05

LORD, *Chemist.*

1. Maxville limestone, "top rock"—Average of three analyses on different samples.
2. Maxville limestone, "bottom vein."
3. Marion limestone, quarries of Marion Stone Co.—Average of three analyses on different samples.
4. Columbus limestone—Average of eight analyses on different samples.
5. Owen's Quarry, Owen's Station, Marion county.

The following series of partial analyses of samples of limestone ore or Baird ore from the Hocking Valley is given. The samples were sent to the State University Laboratory by furnace-companies; they serve to illustrate the variability of ore passing under the same name, and found in the same general position:

	1.	2.	3.	4.	5.	6.	7.
Metallic iron	28.6	28.2	29.0	29.3	45.2	46.7	39.2
Silicious matter	13.7	45.8	17.0	11.2	10.2	17.75	27.6
Phosphorus	0.24	0.09	0.17	0.38	0.30	0.28	0.26
Loss on ignition	28.7	11.6	22.0	24.5	16.9	13.0	13.6

LORD, *Chemist.*

These ores are variously designated as Baird ore, limestone ore, gray limestone ore, ore found in limestone vein, etc.

The average amount of phosphorus in the above series of samples, however, would not vary far from the one that was stated before.

Want of care in sampling has led to many false analyses of the products of not only this region, but of the State at large, and the unsatisfactory way of taking the mean of a large number of analyses is at present the only one by which an approximation to the truth can be reached; unsatisfactory, because one analysis of a carefully averaged sample of ore from a vein is better, as representing its quality, than twenty analyses of pieces supposed to represent the deposit, but really representing the judgment of the sampler.

The works of the Hocking Valley are given in the table of furnaces. The new furnaces at Floodwood Station, on the Columbus and Hocking Valley Railroad, not fully completed, are to be the largest in the valley, with an estimated capacity of nearly 200 tons a day. The furnaces of this region are using more and more the Lake Superior ores, and also considerable mill cinder. This latter material, furnished abundantly by the rolling-mills, is a cheap and valuable source of iron; it yields in the neighborhood of 50 per cent. of iron, though of rather variable composition, its greatest drawback being its high contents in silica and phosphorus, though of the latter element its percentage is extremely uncertain, the "tap-cinder" from the puddling furnace containing

much more than the "flue-cinder" from the reheating furnaces. This variability in the mill-cinder has led to some trouble in its use. The plan is to use Lake ore and mill-cinder in such proportion as to bring the phosphorus in the iron sufficiently low to make it of the desired quality. If, however, the mixture found satisfactory with one grade of cinder is to be used with another, which has much more phosphorus, a falling off in the quality of the iron will be at once apparent. That this may occur will be shown by the following figures. The samples were sent by furnaces as representing cinder in use:

	1.	2.	3.	4.	5.	6.	7.
Iron	47.0	50.6	....	52.40	....	....	....
Phosphorus	0.32	1.80	0.683	1.70	2.21	1.76	2.77

LORD, *Chemist.*

Nos. 5 and 7 are of interest, as they were used in admixture with Lake ore, and the trouble experienced in getting strong iron was charged to the *Lake ore,* which on analysis showed, phosphorus, 0.18, present.

The amount of iron in the cinder is more nearly constant, but still there are occasionally great variations, but usually accompanied by change in the appearance of the cinder. A glassy cinder, which appeared to work poorly, yielded the following analysis:

Silica	35.88
Iron	35.15
Phosphorus	0.84

LORD, *Chemist.*

This cinder is exceptional, but still serves to show the possible extent to which the material, so generally accepted as uniform, may vary. This was not a selected piece, but represented a car-load of material shipped to a furnace.

The total capacity of the iron furnaces of the Hocking Valley district may be estimated at about 150,000 net tons. The production in 1880 was nearly 116,000 net tons of 2,000 lbs., including the Columbus and Zanesville furnaces, which properly belong to and are included in this group of works, as they use the same fuels and ores. By a recent change in the management of several of the furnaces of the Hocking

Valley, the Moxahala Furnace at Moxahala, Fannie and XX Furnaces at Shawnee, Helen and Lee Furnaces at Orbiston, and Monday and the new Floodwood Furnaces have been united under the management of the Standard Coal and Iron Company, of Columbus, Samuel Thomas, President.

At Logan, Hocking county, is a charcoal furnace of an annual capacity of about 2,000 tons, which is geographically included in this district, though more properly associated with the Hanging Rock charcoal furnaces in condition of ores and fuel.

The coals of the Hocking Valley will be fully discussed in the report on coal by the Chief Geologist, Prof. Edward Orton, but for convenience of reference the following analyses of the principal furnace coals, made of samples taken for the Survey, and carefully averaged, are given here:

	1.	2.	3.
Water	5.68	5.26	6.60
Volatile combustible matter	35.79	36.12	34.72
Fixed carbon	54.13	54.59	52.56
Ash	4.40	4.03	6.12
	100.	100.	100.
Sulphur	0.58	0.64	0.64

1. Coal from Akron Furnace, Buchtel, Hocking county.
2. Coal from Suydam's mines, Monday Creek.
3. Coal from Doe's mine.

The details of the smelting and the different works will be discussed in the part of this report relating to the metallurgy of the State.

The Lake Superior ores used in the Hocking Valley district represent most of the well-known mines. They are purchased in lots of various amounts by furnace companies from time to time—at present none of the companies own properties in the Lake region, though there is every probability that some of the large consolidations recently made of the firms in this district may, in order to be more dependent of market variations, arrange to purchase and develop mines in the Lake Superior and Canada iron fields. Canada ore of fine quality has been brought

from such "prospects" to the valley for trial already. The price of the Lake ores in this district is of course, variable, but as a statement of the average $6.00 to $7.00 per ton for 58 to 60 per cent. ore may be taken. The roasted native ore used represents a cost of about $4.40 to $4.50 per ton at the furnaces. These figures represent about the average at present (1883).

The fuel is the item in which the smelters of this district have their greatest advantage; the coal costs at the furnace but $1.35 to $1.50 per ton. Against this low figure, however, comes the large amount required, 3 to 3½ tons being used to smelt a ton of iron. The experiment of coking this coal is to be tried again. Though considered a non-coking coal, there is reason to believe that careful work in the right sort of ovens would result in the making of a serviceable furnace coke ; of course to be of service this coking would follow careful washing. Experiments where the coal was crushed very fine and then washed, have yielded results sufficiently favorable to warrant the expectation of ultimate success.

The making of such a coke would be of great benefit to the valley, as its use would reduce greatly the cost and uncertainty of smelting, and would add greatly to the prospects of the region.

The following summary of a week's run at one of the best of the valley furnaces is inserted, showing the mixture used, the fuel, burden, and flux. The figures were taken from the actual work of the furnace as shown by its books, kindly furnished by the company for the purpose :

Time of Run, 6 Days 17 Hours.

Charges.	Pounds.
Lake ore	197,600
Native ore	544,270
Mill-cinder	131,010
Limestone	565,610
Coal	1.193,400

Iron made, 190 tons of 2,268 pounds ; hot-blast (about 900°) iron, foundry and mill. Other figures and analysis will be given when speaking especially of the character of the smelting.

The Hanging Rock Region.

The Hanging Rock iron region of Southeastern Ohio and Northeastern Kentucky is one of the oldest iron smelting districts west of the Allegheny mountains, and now one of the principal charcoal iron regions in the United States. The title has been given to the region from the village of Hanging Rock, in Lawrence county, Ohio, near which place, as has already been observed, the industry was begun in 1826, and which also was formerly the chief point of shipment for the irons produced by the furnaces of the vicinity. The area so named is included in a narrow belt of territory, having an extension in nearly a north and south direction, with a width on the Ohio River of between 12 and 15 miles, where Ironton may be regarded as situated centrally as regards its east and west limits. In Kentucky this belt has probably an extension of 25 or 30 miles to the south, passing through the counties of Greenup, Carter, Boyd and Lawrence. In Ohio, extending through Scioto, Lawrence, Gallia, Jackson and Vinton counties, to the central part of Hocking it has a length northward of the Ohio River of between 65 and 70 miles, the broadest part of the area resting on the Ohio. Within a radius of 25 miles from Ironton, which is about the geographical center of the region, is included the most important part of its iron industry, both in Ohio and Kentucky. We are concerned here, however, only with that part of the area in the State of Ohio, but most of the observations concerning the character and occurrence of the ores, and the conditions of the manufacture in Ohio apply almost equally well to that part of the region in Kentucky.

The source of the reputation, the wealth and the industry of this Hanging Rock iron region are the rich iron ore deposits lying in several strata near the base of the Coal Measures, and which extend with great uniformity and regularity through the area described. These same ferriferous horizons, however, are quite well marked over the entire area of the coal fields in Ohio, and in the northeastern part of the State are probably represented by the ferriferous horizons of coals No. 3 and No. 4, which are in places in the northern part of the State of some economical importance. In Northwestern Pennsylvania the belt of the celebrated ferriferous limestone has been regarded as the equivalent of these same horizons. Ohio has, however, the most important concentration of iron ore at these levels in the southern part of the State, and no very valuable quantities have been found north of the Licking

River. The abundance and accessibility of these ores in the Hanging Rock region, and the generous supply of fuel in its extensive forests have furnished materials for an iron industry which was represented in Ohio in 1870 by 34 charcoal furnaces, producing 83,900 tons, and 3 stonecoal and coke furnaces, producing 28,000 tons.

The list of the furnaces, on pp. 456–458, showing their distribution and dates of establishment, will exhibit very well the progress and present importance of the iron industry of this region. The Hanging Rock charcoal iron has long possessed a very high reputation in all the western markets for its great purity and fitness for casting purposes demanding strength. Thus it has been the most favored iron at Pittsburgh for the fabrication of ordnance for the Government, and is now specially valued for the manufacture of car-wheels, and for producing superior grades of malleable iron.

The disappearance of the forests under the demands of the furnaces, which is now so apparent throughout the region, increases every year the difficulty of obtaining the necessary fuel, and marks very plainly the fate of the charcoal iron industry. The large amount of wood necessary to sustain a blast-furnace may be appreciated when it is known that some 13,000 cords of wood, the yield of 325 to 350 acres of forest land, are required per year for each furnace. And already a number of furnaces have been abandoned because of the scarcity of accessible timber, though the supply of ore has hardly been much diminished. The use of charcoal must yield, as it has done in all other parts of the State, and is now doing in other States, to the more extended employment of mineral fuel. The manufacture of charcoal iron, nevertheless, will be a matter of considerable importance for some time to come, and the fine quality and high value of the iron will do much to foster its production. That the adoption of any systematic course of timber-growing, to replace the wood consumed, as is done in Sweden and Russia in localities deficient in mineral fuel, is not to be expected in a country like Ohio, where there are such vast stores of coal, and where the land must be of so much greater value for agricultural purposes. Economy and intelligent management will do much to prolong the life of a charcoal iron industry, but the increasing value of the furnace tracts, which are sometimes 10,000 to 12,000 acres in extent, must reduce the profits of the manufacture. These vast tracts of furnace property, embracing the larger part of the region, held as they are by

a few proprietors for their timber supply, have to a great extent been passed over in the general settlement and cultivation of the neighboring portions of the State. And these circumstances have also prevented as thorough a knowledge of the resources of the region in coal, etc., as would have otherwise been the case. The region is about as thinly populated, and, excepting the Ohio Valley, as isolated and poorly provided with means of transportation as any portion of the State. The population is almost entirely dependent, directly or indirectly, upon the iron industry, over a large part of Lawrence county.

The surface of the country in the Hanging Rock region is, like so much of the eastern part of the State, a constant alternation of high hills and deeply eroded valleys, which have been cut out of the originally level surface of the State by the numerous streams which empty into the Ohio. The valleys cutting down through the various strata of rock, coal, iron ores, etc., present outcrops of these beds in positions scarcely surpassed for their accessibility to the miner. And water, though it has been the first miner in cutting out the beds formerly spanning the valleys, has been, nevertheless, a very wasteful one. As the strata all have a dip quite uniform and gentle toward the east, never greater than 30 feet per mile, the ores, coals, etc., which on the eastern side of the region are at or below the bottoms of the valleys, as we go westward, rise until their proper position passes over the summits of the highest hills. Thus the region is limited on the east by the depth of the ores, rendering them difficult to win, and on the west by their absence from the tops of the hills, while between these limits the ores appear on the hill-sides at various elevations.

Allusion has already been made to the great extent of some of the furnace properties, which has prevented the general settlement of the country, and to a great extent its cultivation, and has scattered the points of the manufacture through the region at places more or less removed from one another, excepting, however, the few towns where industries depending on pig-iron have been established, and where the use of mineral fuel has rendered the community of industries more practicable.

Mention may be made here of the towns most important in the manufactures of the region and their means of communication. First, Jackson, in Jackson county, where the excellent "Jackson block coal" or the "shaft" coal is the basis of quite flourishing smelting establishments. At this place the Orange Furnace was the first furnace

in the region where raw coal was used with continued success, and where it has been employed since 1866. There are now in Jackson four blast-furnaces using this fuel, and the native ores of the region, viz., the Star, Fulton, Globe and Tropic, all the result of the enterprise of the vicinity, but they are of quite moderate dimensions. Second, Portsmouth on the Ohio, at the mouth of the Little Scioto River, and beyond the western margin of the Coal Measures. Though containing two large rolling-mills, foundries, etc., it is more important as the chief commercial town of the region than as a manufacturing center. Being the terminus of the Portsmouth branch of the Cincinnati and Marietta Railroad, Portsmouth is the shipping place and business center of a large number of furnaces in the western part of the iron region. As almost every article of supplies necessary for the maintainance of the furnace population is derived from the adjoining parts of the State, the Scioto Valley, etc., the return trade is of very great importance, and in this, Portsmouth is the chief market of the region. Third, Ironton, in Lawrence county, 30 miles up the river from Portsmouth, in 1871 a city of 7,000 inhabitants, is the most important and enterprising manufacturing point in Southern Ohio, besides being the shipping and distributing center for the most important part of the Hanging Rock region in Ohio. It is the largest town on the Ohio River above Cincinnati which has navigation uninterrupted by the fluctuations of the height of the water.

The general position of the iron ores of the region has already been referred to. Very detailed sections, showing their relative positions, may be seen in the reports of the included counties by Prof. Andrews in other portions of the Geological Reports, but a short notice may, however, be given here of the situation, character and mode of mining of the principal ores, while analyses will be given in a subsequent part of this report.

All the principal ores are found within 300 feet of the base of the Coal Measures, and the most important horizon, as regards the value of the ore and the persistency of its development, the horizon of the "limestone ore" has already been mentioned as the probable equivalent of the ferriferous limestone of Northwestern Pennsylvania.

The ores are limonites or hydrous peroxides of iron, and to a smaller extent, calcareous and argillaceous carbonates. The beds were, however, in their original condition as ores, probably all carbonates,

but the oxidizing action of water and atmosphere has changed them, wherever such action was possible, into hydrous peroxides or limonites. The mining only exceptionally being more than stripping off the outcrop, the part of the beds beyond the action of oxidation where the iron is as a carbonated base furnishes but a small proportion of the ores obtained.

There are four perfectly distinct and persistent seams of ore, varying from 4 to 16 inches in thickness, beside several accumulations of kidney ore in the accompanying beds of shale.

The main beds of ore are the "*Limestone ore*," the "*Big Red Block ore*," the "*Sand Block ore*," and the "*Little Red Block ore*." Also in the shales above the limestone ore, nodules or kidneys of argillaceous iron ore are found, which often become very abundant. At different horizons in the region are found other strata of shale which sometimes contain quite important amounts of this kidney, generally, however, at a higher level, and commonly known as "top hill ores." These nodules of kidney ore are never of sufficient abundance to warrant regular mining operations.

The *limestone ore* is by far the most important one of the series, both in richness and quantity, and the one from which two-thirds of the iron is made in the region. Its name arises from its position, overlying a limestone which is one of the most well-marked and persistent features in the geology of the region. This limestone, used constantly as a base line in surveying, furnishes the flux for the furnaces of the region, and is traceable across the Ohio into Kentucky, and northward into Northern Ohio. The limestone ore is found in its original state of a carbonate of iron, but mining operations along its outcrop have developed it mostly as a dark red hydrous peroxide or limonite, lying on the limestone in a regular bed, averaging about 12 inches thick, although in one or two instances basins have been found 5 feet in thickness. The "red limestone" is the richest and most valued ore, and contains on an average about 40 per cent. of metallic iron. It is the most important and widely used ore in the region, and the one more than any other upon which the high reputation of the Hanging Rock irons has been dependent. Without the "red limestone" ore in some proportions, there is little iron made in the region, and those furnaces producing the best quality of pig-iron use it almost exclusively. The ore varies in character from a hard compact limonite ore to one soft and ochreous, and

frequently the mass has hard curling bands running through it which give rise to the name of "curly ore." The red limestone ore is quite pure, containing on an average about 10 per cent. of silica, and the amount of lime and alumina is never very large in the clean ore. Manganese is present, on an average, something more than $1\frac{1}{4}$ per cent., which, however, is scarcely a proportion large enough to affect the quality of the iron directly. Sulphur is present in very small quantities, and in the mean of many analyses rarely exceeds $\frac{3}{100}$ of one per cent. Phosphorus, however, is most always present, and is the most considerable of the damaging impurities, there being on an average about $\frac{3}{10}$ of one per cent.

The "red limestone" ore extends into the hills to a depth depending upon its position and the character of the overlying rocks as regards their imperviousness to the action of water, and passes into the unchanged carbonate ores, which was probably the original condition of the entire stratum. The extent of the change varies considerably, as sometimes the limonitic or red limestone variety prevails, while at other times the change has not been so extended and the carbonates are more abundant. The mining operations, however, having been mostly confined to the outcrops of the seam, the carbonate has always been obtained in smaller proportions than the oxidized or "red limestone" part. This ore is a carbonate more or less calcareous, and the analyses made contain rarely more than 8 or 10 per cent. of the carbonates of lime and magnesia, and in the clean ore but very small proportion of alumina. Very frequently it passes almost imperceptibly into quite a pure limestone containing scarcely any iron at all. It is found in two varieties —the gray and blue limestone ores. The gray limestone ore is somewhat oölitie in character, being formed of a mass of small granules of carbonate of iron cemented together by a calcareous and silicious cement, which, on exposure to the weather, softens and crumbles. When burnt, however, the carbonate is oxidized, the mass becoming of a brick-red color, and though being more difficult to calcine than the other ores, is highly valued for the ease with which it works in the furnace and the character of the iron produced. The blue limestone ore is a more uniform calcareous ore of the limestone seam, quite hard and compact, and not unfrequently passing into a limestone containing little or no iron. These unchanged "limestone" ores vary somewhat in the iron contained, which is by analysis from 28 to 30 per cent., the

blue limestone ore usually being the richer, when roasted they are reported to yield about 40 per cent. of pig-iron. They contain less phosphoric acid, but usually more sulphur than the "red limestone" portion of the seam, and as mixture they are found to work excellently in the furnace, and to a certain extent are self-fluxing from the lime and alumina contained. In places the limestone seam of ores is largely composed of rounded masses or kidneys, all the varieties being found in such condition as the "red limestone," "gray limestone," and blue limestone kidneys already mentioned. From the rising of the strata, as one passes to the west part of the region, it follows that the limestone ore rises and eventually is wanting entirely in the hills. Thus there is but little limestone ore obtained on the west side of the Portsmouth branch of the M. & C. R. R. from Hamden southward, while in the central and eastern part it is almost the exclusive ore. This is the only seam of ore in the region upon which any regular mining operations have been conducted, and the seam being only about 12 inches thick, it requires considerable skill in its extraction. The Hecla Furnace Co., in the central part of Lawrence county, have for some 10 or 15 years pursued quite extensive mining operations by drifts and shafts, and this method of extraction is necessarily becoming more extended.

The Block ores are of much less importance than the ores of the limestone seam already mentioned, and lying beneath this stratum at different depths, from 50 feet and more, are accessible only in the valleys of the western part of the region. They are limonite ores containing from 30 to 40 per cent. of iron, but are chiefly characterized as being more or less silicious. The name "block ore" arises from the strata being cut by vertical seams, which divide it into blocks of quite regular shapes. Each of these blocks is oxidized in concentric layers, giving the ore a banded appearance around a central nucleus, which is often hollow and sometimes is filled with soft ochre or clay. Three beds of these block ores have been recognized. The first is the "Big Red Block" ore, from 6 to 18 inches in thickness, and about 100 feet below the limestone seam. The second, the "Sand Block" ore, about 6 inches in thickness, is about 20 feet below the "Big Red Block," and is generally more silicious in character and poorer in iron than the others. Below this, about 40 feet, is the "Little Red Block" ore, in a seam about 4 inches in thickness, and is usually somewhat richer in iron than the "Big Red Block," to which it is quite similar. In general,

these block ores may be said to average about 8 or 10 inches, and to yield in the furnace about 33 per cent. of iron. They are used in many of the furnaces of the region, but rarely in a larger proportion than $\frac{1}{4}$ to $\frac{3}{4}$ of the limestone seam. Alone, they are not found to work well from their poverty and silicious character; thus, in 1870, the Empire furnace was using $\frac{4}{5}$ of these ores and $\frac{1}{5}$ of the limestone and kidney ores, and there were required about $3\frac{1}{2}$ tons of ore and from 2 to 4 times the usual amount of lime for flux to make a ton of iron. The furnace has since been abandoned.

Various estimates of the yield of these seams of ore in the entire region have been made, but they can only mislead, as from the manner in which the beds have been cut out by the valleys a true estimate of the territory actually covered by them becomes almost an impossibility. Prof. C. Briggs, jr., of the former Geological Survey, estimates "that the iron region from the Ohio river, near Franklin furnace, northward by Jackson to the Hocking river, occupies an area equal to an unbroken stratum 50 miles long and 6 miles wide, capable of yielding 3,000,000 tons of good iron ore to each square mile, and that the quantity of ore is so great that Jackson, Lawrence and Scioto counties are capable of producing 400,000 tons of iron annually for 2,700 years." This is unquestionably an overestimate. We may, however, consider, assuming the very low figures of 10 inches and specific gravity 3, for the thickness of the ore, that each acre underlaid by it will yield about 2,843 tons (of 2,240 lbs.) of iron ore, while the furnace-men estimate about 2,800 tons per acre.

Beside these stratified ores mentioned, the shales of the Coal Measures contain frequently large accumulations of kidney ore, the argillaceous carbonate or clay ironstone. They occur in masses from very large size to those of quite small dimensions, usually, however, as flattened nodules about the size of one's fist. This ore is exceedingly uncertain in its distribution, as sometimes the nodules will be so closely approximated as to form almost a continuous stratum, while more frequently they are scattered without any regularity through the entire bed of shale. Hence, from their manner of distribution, it is an ore which very rarely, if ever, will pay for a regular system of extraction. Quite considerable quantities are, however, obtained by stripping, or simply by collecting them from the surface or the valleys, where they have been washed or weathered out from the enclosing rock. This kidney

ore is often called "top hill ore" in the region, referring to the position of its occurrence, much being found at a considerable elevation above the regular ores. It is an ore highly appreciated for its ready reducibility, though on an average it rarely contains more than 33 per cent. of iron. The most considerable deposit is found in the bed of shale which usually immediately overlies the limestone seam of ore, and in the process of stripping off the shale to obtain the limestone ore, the kidneys are separated from the enclosing shale. At different horizons above the stratum other accumulations of kidney ore are also found, but nowhere is any method applied to their exclusive extraction.

A few remarks about the manner of obtaining the ores in the Hanging Rock region may perhaps be added here with profit. In procuring the ores the furnaces draw their supplies almost entirely from their own estates, and when they are bought, the ores are valued at about 50 cents per ton in the ground. The ore beds, as already mentioned, have no great thickness, varying from 4 to 18 inches, and thus far, with but one or two exceptions, no regular underground mining operations have been sustained. On the property of the Hecla Furnace, however, considerable quantities have been obtained for several years by drifting and by shafts sunk upon the limestone seam. The sections made by the valleys through the ore-bearing rocks present continuous outcrops of the ore beds, and afford innumerable points of attack. The usual mode of obtaining the ores is the very simplest possible, and consists in merely digging away the outcropping rock above the ore beds, and then taking up the ore from the bottom of the excavation, or, as it is called, benching or stripping. The stripping thus advances regularly, cutting away the hill-side and extracting the ore, until the limit is reached, when the cost of removing the material over the ore is not repaid by the value of the ore obtained. When carefully conducted this limit is usually reached when the thickness of the overlying rock is about 12 feet for a 12-inch seam of ore.

Fortunately, in this region the rock usually overlying the ore is a soft and pretty easily removed clay shale, and in the case of the limestone ore, the superposed bed of shale contains nodules of clay ironstone irregularly distributed, which are separated in the progress of stripping. On the great banks of waste thus thrown out in benching, one may ride, as on a natural terrace, for miles in and out of the successive valleys, and in passing through the region, so far as the eye can reach they are

a marked feature in the landscape. The cost of this method of stripping may be approximately estimated as follows: one man can remove 12 cubic yards of earth per day, at a cost of $1.50, or 12½ cents per cubic yard. Assuming the depth of earth to be 12 feet, and the ore as 1 foot in thickness, each 12 cubic feet of earth removed will expose 1 cubic foot of ore, which may be removed at 30 cents per cubic yard. The cost per ton of ore will hence be, regarding 12 cubic feet of ore as equal to 1 ton of 2,240 pounds:

Removing 5.33 cubic yards of earth, at 12½ cents	$0 66
Removing 0.44 cubic yards of ore, at 30 cents	0 13
Cost of stripping per ton of ore	$0 79

For a seam of 6 inches the cost would be on the same estimate, $1.46, and for an 18-inch seam, $0.57. In stripping for the ore no very systematic method has been pursued, for, when the ore is wanted the miner, or rather ore digger, has much liberty as to where he shall dig the ore, and he opens the seam much as he may choose, being paid so much per ton of 2240 pounds, delivered at the furnace, the company furnishing the haulage. Benching is unquestionably the cheapest method, and for those ores below 1 foot in thickness the only one possible, but for seams of one foot or more, regular mining operations could be adapted. The limestone ore, as stated, has been thus obtained in some instances, and possibly one of the block ores would also warrant a similar course. The course best adapted would seem to be to run good roomy entries, about 100 feet apart, on the seam, either from the hill-side, or, where it is deeper, from shafts, and then to connect them by parallel galleries. The entries would thus serve for mining out the ore in cars, and the ore could be removed in the cross galleries by the "long-wall system." This method enables all of the ore to be worked out, and requires but little timbering, for as fast as the ore is stripped up the refuse can be thrown behind, and the roof allowed to fall in. A rough estimate of such a course of extraction, less the expense of maintaining the tram-ways, cars, etc., can be approximated as follows, assuming the cost of mining at $0.75 per cubic yard, and the weight of ore as 187.5 lbs. per cubic foot (specific gravity, 3): in a bed of ore, 1 foot thick, each cubic fathom of earth removed yields 36 cubic feet of ore, or 3 tons, which will thus cost $2.00 per ton.

Between the years 1870 and 1873 the value of these different ores

as delivered at the furnace was, per ton of 2,240 lbs. on an average, for the limestone ores, $3.85; for the kidney ores, $3.50; and for the block ores, $3.25. During 1880 the same ores were valued at $2.75 to $3.00.

Beside these native ores some of the rich hematites of Lake Superior and Missouri are brought to the region. The former have been used at the Logan furnace, while the latter are employed constantly in large proportions at the Belfont furnace in Ironton, and will be also largely used by the other furnaces at that place. In addition to their employment in the blast-furnace, considerable quantities of the Missouri ores are consumed by the rolling-mills as "fix" or lining to the puddling furnaces. The price of these ores is, however, always high, which is in part compensated by their richness and superior quality. With the native ores they work in the furnace usually better than when smelted alone, and the native ores producing a red short iron, and the Missouri and Lake Superior ores a cold short iron, a proper mixture is said to produce a neutral iron, or one having neither of these usually objectionable qualities. In 1870 the Lake Superior ores cost about $11.00 per ton at Logan, and the Missouri $12.00 at Ironton; in 1880 the prices of Missouri ores were about the same. With good means of transportation, Ironton should obtain the Lake ores at only a small advance, if any, above their cost at Pittsburgh, while for the Missouri ores it is more favorably situated. Quite a considerable quantity of the dyestone or fossil ore from Eastern Tennessee has been brought to Ironton, but because of the phosphorus, which it always contains in notable proportions, it makes a cold short iron, and as a lining or "fix" for puddling furnaces it is useless for the same reason. For a common grade of iron, however, it may be successfully used as a mixture in the furnace. Analyses and more complete descriptions of these ores are given in another portion of this report, where iron ores are considered as a whole. Regarding the other ores, as those of West Virginia, Old Virginia, etc., which may be brought in connection with this region, we are at present but imperfectly informed.

In preparing the ores for smelting, all the native ores are burnt in large piles before charging into the furnace. As fast as they are brought to the furnace the ores are stacked in large piles, which are built upon a bed or grate of timber, and interstratified with fine charcoal or the waste breeze, the combustion of which supplies the heat necessary for their calcination. These piles are often of very large size, containing

several thousand tons of ore. They are usually about 10 feet high, from 10 to 20 feet broad at the base, sloping upward to the top, which is flat, and so long, often, that while the burnt ore is being removed from one end fresh ore is being added at the other. The time necessary for the calcination depends evidently upon the size of the pile, and also the need in which the furnace stands in reference to a supply of ore. They answer thus at the same time as calcination heaps and storage piles. Sometimes they burn for 6 or 8 months, though it is impossible to obtain any accurate information regarding the time, labor, expense of fuel, etc., consumed in the operation. By burning, the ores lose about 20 to 30 per cent. of their original weight, and are proportionally enriched in their yield of iron.

As regards the fuel of the region, mention has already been made that charcoal forms the exclusive material used in 34 of the 41 furnaces, and that it is only within a few years that attention has been turned to the employment of the coals in smelting the ores of the region. The varieties of wood, most common in the region, are oak, hickory, maple, beech, ash, poplar, walnut, and some pine. The magnificent forests have furnished an abundant supply of charcoal, but its rapid consumption, as stated, has caused the abandonment of some furnaces, while others more provident, permitting the growth of new timber, after the lapse of 20 or 25 years, are now cutting a second growth for charcoal. It is reported also that in some instances a third growth is being obtained from the same land. The amount of charcoal consumed annually by a furnace, may be illustrated by the following statements kindly furnished by the proprietors of the Pine Grove and Hecla furnaces: Pine Grove, hot-blast furnace, in 1869, produced 3,102 tons (of 2,268 lbs.) of iron, and consumed 11,045 cords of wood, which yielded 36.8 bushels per cord, or 406,456 bushels, or at the rate of 131 bushels of charcoal, or 3.56 cords of wood per ton of iron. The Hecla, cold-blast furnace, in 1867, for a blast of 218 days, made 1,980 tons (2,268 lbs.) of iron, and consumed 393,000 bushels of charcoal, or 201 bushels per ton of iron. It is usually stated that a furnace will consume the wood from 250 acres of land per year, hence to ensure a perpetual supply of timber by allowing its regrowth where once cut, such a furnace would require from 800 to 1,000 acres of wooded land. The wood is valued at about 50 cents per cord in the tree. The charcoal made and delivered at the furnace was estimated in 1870–71 to cost on an average

$8\frac{1}{10}$ cents per bushel. All this work of cutting the wood and burning the charcoal is performed by contracts, so much being made per load of 200 bushels of charcoal delivered at the furnace by the furnace teams. The special mode of charcoal making is more fully described subsequently; it will suffice to say here, that it is all made in pits or piles, which are built convenient to the wood to be used, and within easy access to water, which is essential. These piles contain about 40 to 80 cords of wood, and the operation lasts about 21 days, yielding about 38 to 40 bushels of charcoal per cord. From the hilly character of the country, and the general roughness of the roads, this method seems the one best adapted, as a team which could not draw a couple of cords of wood can easily haul 5 cords when converted into charcoal. The wood is usually felled in the winter, and the clearing takes place in summer and fall. The charcoal is drawn to the furnaces, where it is stored in sheds, by large wagons holding about 200 bushels, and requiring often 4 or 5 yoke of oxen. The loss from abrasion is consequently quite considerable, but the waste is utilized in burning the ores.

The consumption of charcoal per ton of iron is given elsewhere for the furnaces as accurately as it could be ascertained, but the average consumption may be stated as 155 bushels, or allowing 20 lbs. per bushel, 31 cwt. per ton (2,268 lbs.) of iron with hot-blast, and 215 bushels, or 43 cwt. per ton (2,268 lbs.) of iron with cold-blast.

The coals used in this region are discussed in the report on coals, and will not be treated expressly here. The use of charcoal is so characteristic of this region that the above review of its manufacture is important in order to understand the economic relations of the charcoal iron industry. A few additional data relative to the growth of timber and yield of charcoal, collected since the above was written, by Mr. Newton, may be added here. The growing scarcity of wood has led to the recutting of considerable of the land on which second and third growth timber is found.

The timber land, as originally found, yielded about 40 cords to the acre, along and near the Ohio river; back in the country probably a little less. On recutting this same land, after an interval of 25 years, the yield was in the neighborhood of 20 cords to the acre, and according to the estimates given by the furnaces recutting timber, the annual increase over this figure for the next 20 years was about at the rate of a

cord an acre, so that at 45 years the original 40 cords to the acre would be reached; this rate, however, will hardly hold to that extent.

The third crop is more rapid than the second, owing probably to the fact that the second crop comes largely from the seed, while the third comes from the stump. The above statements were kindly furnished by Mr. John Campbell and Mr. Johnson, of Ironton, whose long experience in charcoal iron smelting makes their statements of especial value.

The charcoal is delivered at the furnace by the burners, who are paid by the load. The charcoal bushel of the Hanging rock region is of 2,688 cubic inches, and 200 bushels nominally make a load. These burners cut the timber either on their own or on the company's land during the fall and winter, from about October to April, and they burn during the summer. The universal mode of burning is in piles or "meilers." The charcoal burner employs the laborers and conducts the whole operation, having no connection with the company. The pile is built on a level piece of ground, the sticks cut about 4 feet long, being placed on end, and fitted as closely as possible, all interstices being filled with small wood; the pile is made usually in two layers, and when complete is covered with damp leaves and earth. The burning occupies 10 to 12 days, the building about a week, and the drawing, which is done a little at a time to avoid fire, about 5 or 6 days more.

The charcoal delivered at the furnace is measured by the load. The wagons being guaged are filled level, a load being about 200 bushels.

The charcoal of most of the furnaces is measured, not weighed, into the furnaces, it being claimed by the men that this method serves better, as the variation in dampness of the charcoal does not affect the quantity used in the furnace, as would be the case were the charcoal weighed. This practice makes it difficult to ascertain fairly the working of the furnaces, owing to the want of certainty as to how much a bushel of charcoal weighs. At Pine Grove furnace, near Ironton, the coal charged is, however, weighed, and taking the sum of the charges for the year, and the coal received in loads, the average weight then was 23 lbs. to the bushel of 2,688 cubic inches. This weight includes the "brands" or partly charred wood, butt-ends of sticks near the bottom of the charcoal pile; these brands are received with the charcoal, provided

they do not go above a certain proportion. At the furnace quoted, this limit is 5 "baskets" of brands to the load. These "baskets" hold from 1 to 2 bushels; of course, these brands are specifically much heavier than the charcoal, and increase thus the average weight of the bushel.

As this matter of relation between weight and measure is of importance, the following figures are given, taken from the journal of the Charcoal Iron Workers' Association. The bushel is 2,688 cubic inches.

Furnace.	Wood.	Weight bushel charcoal.
Alabama.	Oak and pine.	19.22 lbs.
Port Leyden. N. Y.	Birch, beech and maple.	23.32 "
Midland, Mo.	" Hard wood."	25.00 "
Duluth, Minn.	"Soft wood."	17.00 "

These figures show how extremely uncertain the estimate by bushels is as to the real quantity of fuel used per ton of iron. This subject will be treated further when discussing smelting. As to quality of charcoal, the smelters of the Hanging rock region claim that the second growth "sapling" charcoal is the best, carrying more ore to the bushel in the furnace. Whether this is, as is very probable, due to the increased weight of the bushel, in this smaller and more compact product, the figures are wanting to decide.

The Hanging Rock district is one of the oldest in the county, and the character of the works is generally the same—small furnaces, stone stacks, and rather light and crude machinery. These subjects will be discussed more fully further on in this report.

For convenience of reference the following analysis of the ores of the district, some made in the Laboratory of the State University at Columbus, and others furnished by the kindness of some of the furnace companies in Lawrence county, are here given:

	1.	2.	3.	4.	5.
Silica	13.61	15.40	26.22	17.90	25.39
Alumina	3.00	....	0.68	....	....
Oxide iron	56.00	....	61.34	71.09	....
Lime	2.90	....	5.24	....	1.25
Magnesia	1.95	....	....	....	....
Sulphur	0.34	....	.117	....	.732
Phosphoric acid	0.32	....	.408	0.68	....
Oxide magnesia	....	....	.78	....	....
Iron	39.2	27.0	42.93	49.76	....
Phosphorus	....	0.36	0.18	.29	.172

1. Block ore, Vinton county.—Chemist, Lord.
2. Blue ore, Athens county.—Chemist, Lord.
3. Ore, Pine Grove Furnace.—Chemist, H. Weber.
4. Ore, Pine Grove Furnace; Newcastle Red Block.—Chemist, H. Weber.
5. Blue Block ore.—Chemist, H. Weber.

Besides the works in the districts above described and discussed in detail, there are a few unimportant ones scattered over the State, which belong to no district especially. These are the Manhattan Furnace at Ironville, Toledo, Lucas county, and the Maumee and Paulding Furnaces in Paulding county. They use Lake Superior ores and charcoal. The estimated capacity is about 15,000 tons annually. They represent the southern limit of the charcoal iron industry of Michigan, where Lake ores are reduced by charcoal.

This completes a review of the geographical distribution of the iron works of Ohio, together with a discussion of the characteristics as to ores and fuel of each district. To avoid repetition the separate works and modes of smelting were not treated of, it being thought more desirable to make of the metallurgy of iron in the State a separate section, complete in itself. With this object in view, as many facts relative to the forms of furnaces, treatment of ore, equipment in engines, stoves, etc., with figures relative to the proportions of ores, fluxes, etc., and the burden of ore to fuel, with analyses of products, as the limited time and means at the disposal of the Survey would permit, have been collected. Through the courtesy and kindness of many of the furnace companies, access was given to their furnace-books and drawings of furnace lines furnished, which have been of great assistance in preparing this part of the work.

The treatment of fuel, converting it into coke, forms the subject of a separate chapter.

THE METALLURGY OF IRON IN OHIO.

The preparation of the ore in this State consists in most cases of merely a preliminary roasting more or less complete. The preparation of the ore by washing, used in other parts of the world, has not been introduced here. The desirability of special attention to this branch of preparation has been apparent in many parts of the country, where

ores somewhat similar to the Ohio limonites and carbonates are found. With many of the Coal Measure ores used in Ohio, considerable low grade material and clay are mixed. The introduction of such material into the furnace tends to bring down the value of the whole charge and to increase the cost of smelting per ton of iron, to diminish the effective capacity of the furnace and to render the quality of the iron less uniform. "Washing," where practiced, consists in a treatment of the ore by a stream of water, either over revolving screens or in sluices, by which the clay and other lighter and injurious material is removed. The charcoal furnaces of Northern Alabama have adopted in some cases this method of treatment, and it possibly could be used in the case of some of the Ohio ores with benefit, though their low percentage of iron would forbid any expensive treatment. The roasting of the iron ore previous to smelting is practiced throughout the State of Ohio. The method in almost universal use is of roasting in open piles, of which the dimensions vary greatly from district to district with the character of the ore. The limestone ores and brown hematites of the southern districts are roasted, either with charcoal breeze or with raw coal slack. The ore is usually roasted at the furnace, but not in all cases; sometimes, as at several points on the Iron Railroad near Ironton, the ore is brought over to the most convenient distributing point, and there made into piles and roasted. A similar arrangement is employed by the mining company known as J. R. Buchtel & Co., in Vinton county. This company owns lands along the lines of the Ohio and West Virginia Railroad, in Vinton and Hocking counties, located 20 or 30 miles along the railroad. The company is composed of a number of the furnace owners of the Hocking Valley, united under the above name. The ore is mined at various points, roasted, and sent to the furnace from three or four stations along the line of the road. The piles of ore at the Lawrence county charcoal furnaces are built on a leveled space, generally on the bank above the furnace, on an understratum of wood; above this the ore is piled, with alternate layers of finely broken charcoal, resulting from the screening of the charcoal used in the furnace. The pile is built to a height varying from five or six to ten or fifteen feet, and covering a space of ground about ten feet in width by sixty or more in length. Frequently several such piles are built side by side, and in this way cover a square of ground possibly thirty or forty by fifty or sixty feet. The pile is fired at the bottom.

The fire gradually extends through the mass and expels a portion of the volatile material (carbonic acid and water). The method of building the piles with coal slack is exactly the same. These piles will contain from a few hundred to a thousand tons of ore. The length of time required to complete the burning will vary from thirty days to six weeks, or in the case of some blackbands, some months, according to the size of the pile and the kind of fuel, taking more time with coal than with charcoal.

The evils of this method of roasting are numerous. In the first place, the roasting is imperfect, pieces frequently being found among the ore almost entirely unburned.

A prominent charcoal smelter says in regard to the completeness of roasting:

> "For the last ten years in this district there is hardly a furnace that has not made the serious mistake of burning its ore too lightly. We have done little more than smoke it, then have fed it into our short furnaces, and attempted to make the best iron. Our ores, and more particularly our gray ores, are especially hard to burn. These are found in detached masses in the potters' clay and fire-clay which overlie the regular vein of the ore, large balls from the size of the fist upwards, and it has been the universal custom to get them into the wagons somehow, and haul them to the kilns, pile them up, putting a little charcoal breeze under them, and smoke them."

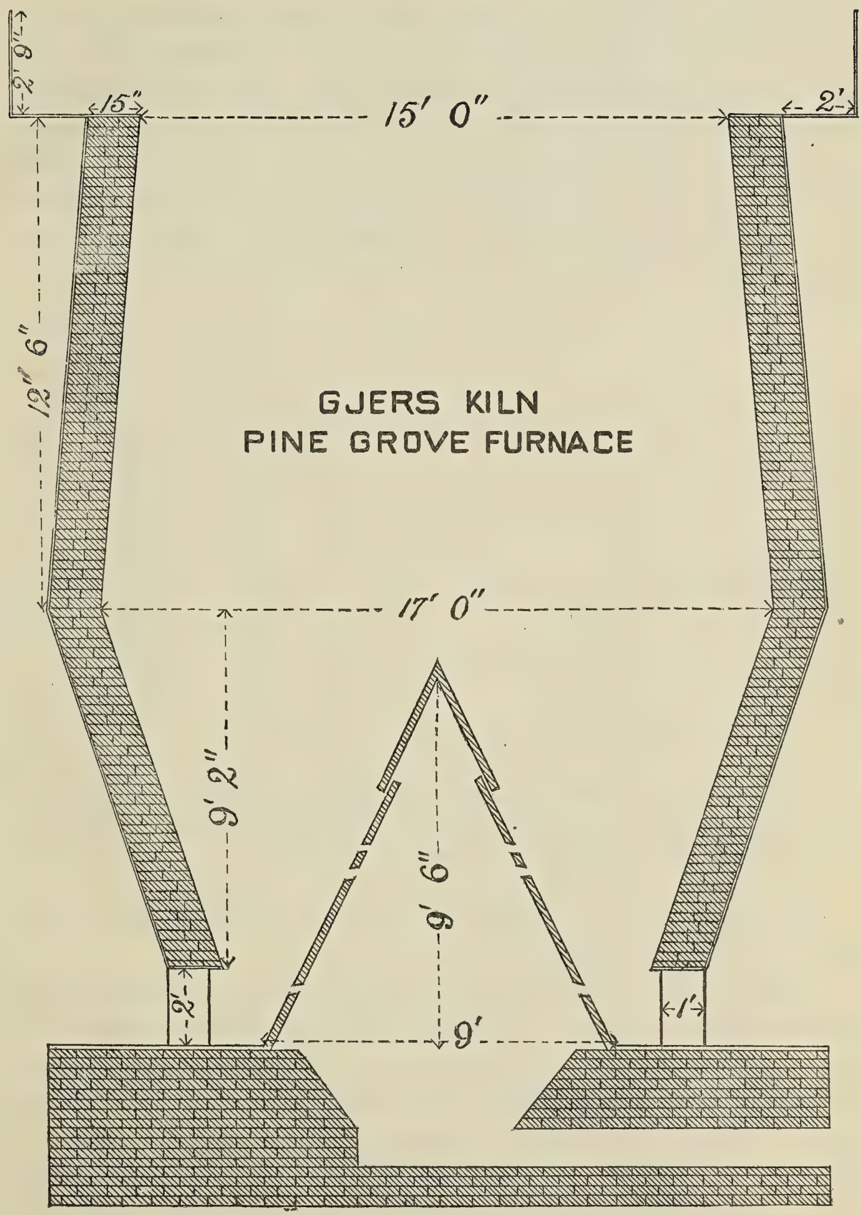
Another drawback to this method of pile-roasting is the large amount of ore kept on hand, representing money lying idle. In the burning of these piles, besides the evil of incomplete roasting, there is ever liable to occur, either from the addition of too much fuel or the action of winds, local overheating, resulting in the formation of large masses of fused or agglomerated material, known by smelters as loups, of less value in the furnace than well roasted ore, tending to cause sticking or hanging of the furnace and irregular working. The composition of these loups is a silicate of iron, and is similar to that of mill cinder. Loups are not only produced by high heating, but by the presence of the lower oxides of iron. The higher oxides represented by the hematites and red ores do not form these fusible masses so readily, and hence can be roasted in piles with less danger; whereas, the carbonates represented by the blackbands and blue limestone ores, containing oxide of iron as protoxide, form loups very easily, silica making a very fusible compound with protoxide of iron, but not with the sesquioxide.

The cost of this method of roasting is very small, owing to the

excessive cheapness and small quantity of the fuel used, the amount of which is about one-tenth that of the ore, though it is not accurately measured. One object of roasting is the expulsion of sulphur, which is quite incompletely attained in piles. And where the ores contain considerable, as is the case with some of the gray ores, the imperfect expulsion of the sulphur may lead to serious trouble in the working. This description of the method of roasting in piles applies to all the furnaces using native ores in the State, the fuel being, as stated, charcoal breeze at the charcoal furnaces, and coal slack at the coal furnaces. The use of kilns for roasting ore, which has been found so advantageous in many parts of the world, has been almost untried in Ohio. At the Monitor furnace, however, four miles from Ironton, an iron kiln has been built out of the upper part of the mantle of an old furnace; this primitive kiln, consisting of an iron shell about 8 feet in diameter, lined with fire-brick, and supported at the bottom on stone blocks, and having a total height of only 17 feet, is charged with ore mixed with charcoal breeze, and the burned ore drawn out at the bottom. This burns the ore in from twenty-six to thirty hours, the ore is uniformly burned, and does not loup or melt together. This one kiln furnishes nearly enough ore to supply the furnace. The charges in this kiln are not weighed, and consequently precise figures as to the amount of coal used could not be obtained, but the filler states that about an inch of breeze was used to a foot of ore. Experience with good English kilns has shown that in proper kiln-roasting one-fifteenth to one-twentieth the weight of the ore is all the fuel that is required.

The new furnace now being built at Hanging Rock, by Means, Kyle & Co., is to be equipped with kilns built after a slightly modified plan, of the "Gjer" kiln. This kiln, having a diameter of 17½ feet at top, 19½ feet at middle, and 13½ feet at bottom, is provided with a series of flues by which air is brought to a cone of cast iron in the center of the kiln. The advantage of this arrangement is that the ore is prevented from overheating, and is fully supplied with air, by which all the lower oxides of iron are converted to sesquioxides. Figure I gives a sketch of ths kiln. These are the only cases of kiln-roasting in the State. The blackband ores of Tuscarawas and Stark counties are roasted in piles with coal slack, or in the case of the Mineral Ridge blackbands, where the proportion of carbonaceous matter is large, are

FIGURE I



burned without the addition of fuel, being simply made into piles of irregular shape and allowed to burn.

The loss of weight in burning varies of course with the character of the ore. It is as high as 40 to 50 per cent. in the blackbands spoken of, and as low as 20 to 30 in the limestone ores. After the ore is roasted, and when taken to the furnace it is usually screened to remove the final portions of the accompanying gangue clay and dirt. This partial cleaning of the ore constitutes all the further preparation it receives, going then directly to the furnace. The difference between roasted and unroasted ore will be shown by the following analyses:

	1.	2.	3.
Protoxide of iron	....	31.16	38.8
Sesquioxide of iron	63.78	7.40	....
Silica	22.15	22.20	15.80
Lime	1.12	3.18	2.97
Magnesia	0.42	1.96	1.26
Alumina	7.43	6.06	10.64
Oxide of manganese	undet.	0.93	
Carbonic acid and organic matter	....	22.80	23.75
Water	0.95	3.17	2.78
Phosphorus	0.18	0.06	0.08
Sulphur	0.38	0.12	0.15
Metallic iron	44.65	29.40	30.20

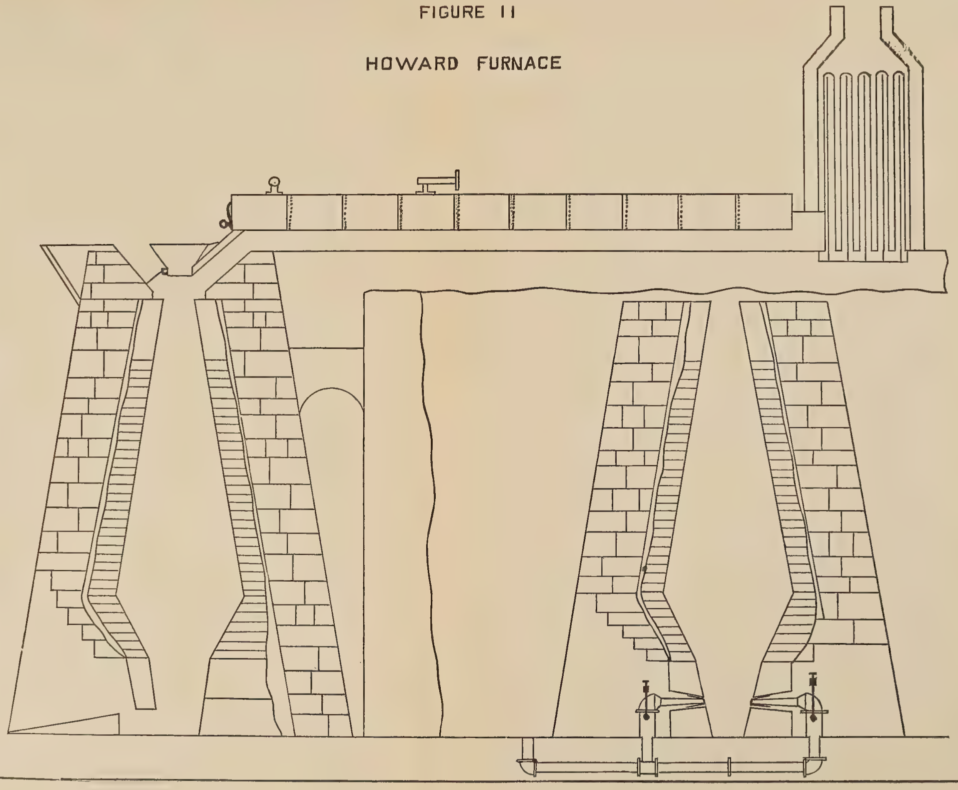
1. Average sample roasted limestone ore, Bessie Furnace, Straitsville, Ohio.
2. Gray limestone ore, raw, from Crafton, Hocking Valley, same ore as above.
3. Gray limestone ore, Bessie Furnace, same as No. 1.

The increase in the sulphur in the roasted ore is probably due to the coal slack used in the pile.

In other parts of the country the roasting of ores has received more special attention. Kilns of numerous devices have been built for the more perfect roasting of iron ores, and described in the various journals with the object not only of less expense, but more complete calcination. Of these kilns the Westmann kiln and Taylor kiln may be mentioned as examples. They have been tried in New Jersey, and at the Shelby Iron Works of Alabama. Both are particularly adapted to the elimination of sulphur from the ore, this object being accomplished by the heating of the ore out of contact with the fuel, and in such a way as to secure an abundant supply of air.

FIGURE 11

HOWARD FURNACE



The character of the furnaces of the State will be perhaps best discussed by taking up the different regions somewhat in detail, and describing the principal works of each district, beginning with the Hanging Rock region as one of the oldest and most individual regions of the State; the works of this district are of two classes—the charcoal furnaces and bituminous coal furnaces. The charcoal iron industry of the Hanging Rock region has been discussed already at some length. The charcoal furnaces of this district are mostly small, usually provided with stone stacks, and are large square piles of masonry built against the side of a hill, and so located that the top of the furnace is on a level with the bank on which the ore is burned, the charcoal stored, and in some cases the buildings of the company located; below is the casting-house, frequently a simple wooden shed, sometimes a brick building roofed with iron; this is connected with the engine-room in which the blowing engines are situated. The boilers of almost all these charcoal furnaces are located above the furnaces, and are heated by the combustion of the gases from the top of the furnaces. The charging is accomplished by means of ore buggies, the ore being weighed usually on a simple beam scale, and the charcoal almost invariably measured. These furnaces, situated generally at some distance from towns of any size, and surrounded by timber lands, comprising in some instances from ten to twelve thousand acres, form an institution of rather peculiar interest.

The company invariably keep a store at the furnace, which forms the base of supplies for all the employes of the corporation. These live at or near the furnaces in small places rented from the company, who do, or did formerly, in some cases, pay off their hands in part in orders on the store; of course such a system as this led to some abuses, which gave rise to trouble at one time and another; the profits made by the store, it was claimed, were excessive, and that laborers at the end of the year found that their wages were about all required to cover their store account. That this was the case in some instances there can be little doubt, one storekeeper stating that (at least during the census year) the store profit averaged sixty per cent. *ad valorem.* This was probably exceptional.

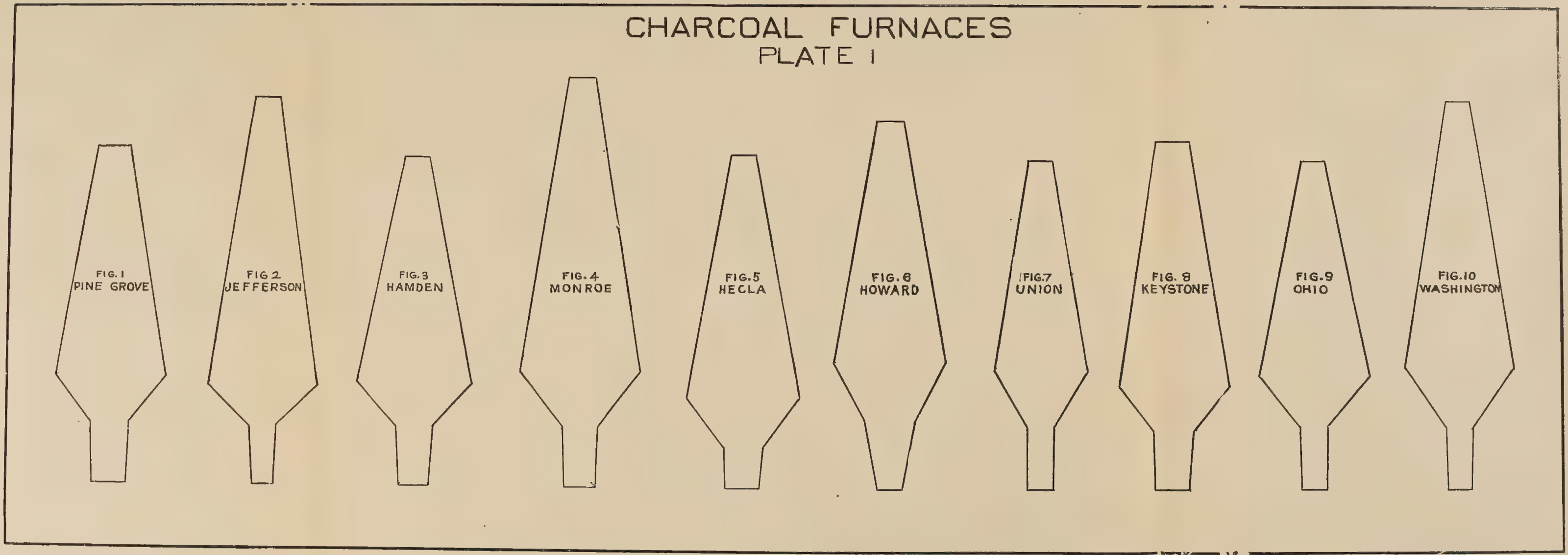
Figure II, representing the general arrangement of one of the charcoal furnaces of this region, is taken from a plan furnished by Mr. Campbell, of Ironton, and printed in the Journal of the United States Association of Charcoal Iron Workers. The works at Ironton com-

prise at present one charcoal furnace and five coal and coke furnaces. The largest of the stone coal furnaces are the Blanche and Grace furnaces, about a mile north of the railroad depot, which were originally built on the Ferrie self-coking plan, but have been altered, owing to the slow working of the system, and are now run regularly as ordinary coke furnaces. One of them, Grace furnace, has however never been lined or put in blast. The big furnace is 86 feet high. At present it is making about 50 tons a day. The furnace is somewhat burned out, and running on part time.

The equipment of the works is on a very elaborate plan. The buildings of brick, roofed with iron, comprise a large and finely equipped stock-house, casting and boiler-houses. The steam-hoist, which supplies both furnaces, is built with an iron frame-work and open sides. The furnace has vertical engines and cylindrical boilers. The blast is heated by Whitwell fire-brick stoves. The works have never run to their full capacity, owing to difficulties in the management, and in the supply of stock, but are considered as having a capacity of 66 tons a day for each stack. A feature of some interest in the works is the method by which the slags are removed from the furnaces, it being one of the few furnaces providing for this being economically done. The slag is run into cast-iron buggies through a slag discharge or channel of cast-iron, and when the buggy is filled it is drawn off on a track to the river bank, where the slag is dumped. The hot slag-bed, so common at many furnaces, is thus avoided. Beyond the Etna furnace is the Sarah furnace of H. Campbell & Co., a comparatively new furnace, well equipped, and making over thirty tons of iron per day. The furnace is provided with one upright blowing engine, with Whitwell stoves, and is one of the best equipped furnaces in the district.

The Belfont furnace is situated near the city. Its companion, the Grant, has been quite recently torn down, to make room for the Kelly Nail Co. now being built. The Belfont furnace makes a specialty of mill iron, which is cast into chill-beds or molds of cast-iron instead of sand; this chilling diminishes the amount of sand held by the iron, and causes a less destruction of fix in the subsequent operation of puddling for the manufacture of wrought-iron.

Maggie furnace, of the New York & Ohio Iron and Steel Co., is 58 feet in height by 16 in the bosh; it is equipped with Player pipe stoves and two blowing engines, 66 by 54 inches; this furnace is worked in


CHARCOAL FURNACES
PLATE I
FIG. 1
PINE GROVE
FIG 2
JEFFERSON
FIG. 3
HAMDEN
FIG. 4
MONROE
FIG. 5
HECLA
FIG. 6
HOWARD
FIG. 7
UNION
FIG. 8
KEYSTONE
FIG. 9
OHIO
FIG. 10
WASHINGTON

connection with the rolling-mill of the company. The other works along the Ohio river in this district are the Monitor furnace, a small charcoal furnace, which is peculiar in being built with an iron mantle instead of the customary stone stack seen elsewhere in this district; it has been before mentioned as employing a kiln for roasting ore; and the Hanging Rock furnaces of Means, Kyle & Co. This company is building at present, in addition to the furnaces they already have, a large stack of 16 ft. bosh by 72 ft. height, of which the lines are given in plate No. II.

The furnace is to be equipped with the Gjer kilns spoken of before. The charcoal furnaces of the district lying back from the river, and situated through Lawrence, Scioto and Jackson counties, will be found given in name and capacity in the table of the furnaces of the State on pages 456–458. In regard to the outlines of the furnaces of the district, plate I, annexed gives as nearly as could be obtained the interior forms of a number of the best known of these charcoal furnaces.

The following tables give the dimensions of the same furnaces from which the sketches were made, also the capacities, as closely as could be calculated, of each furnace, it not having been possible to get in all cases exact measurements, but sufficiently close approximations were obtained to give nearly the volumes:

Charcoal Furnaces.—Capacities in Cubic Feet.

Name of Furnace.	Shaft.	Bosh.	Hearth.	Total.	Production per 24 hours.	Cubic feet per ton (2000 lbs.) produced in 24 hrs.
Pine Grove	968.67	194.4	66.36	1,229.40	17.5	70
Jefferson	1,173.66	166.26	24.09	1,364.01	11.2	122
Hamden	844.80	160.0	47.86	1,052.70	16.3	64
Monroe	1,269.10	314.4	51.20	1,634.70	19.3	84
Hecla	858.30	237.0	42.36	1,137.70	15.0	76
Howard	969.00	315.8	77.33	1,362.13	15.0	91
Union	563.68	175.06	33.56	772.32	11.5	67
Keystone	795.60	302.7	51.02	1,149.30	14.0	82
Ohio	850.78	206.2	31.48	1,088.46	15.0	72
Washington	1,053.90	247.4	29.48	1,330.80	15.5	85

CHARCOAL FURNACES—DIMENSIONS.

Name of Furnace.	Height of furnace.		Height of bosh.		Height of hearth.		Height of tuyers.		Diam. of throat.		Diam. of bosh.		Diam. of hearth (top).		Diam. of hearth (bottom).		Diam. at tuyers.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Pine Grove.....	33		10	6	6				3	3	11	3	4		3	6		
Jefferson	38		9	9	5	9		33		32	11		2	9		26		
Hamden.........	32		10		6			34		30	11	6	3	8	3			39
Monroe	40		11	4	6			32		34	12		3	6	3	2		40
Hecla	32	6	9		4			32½	2	6	11		4		3	4	4	
Howard	36		12	6	6	6		32		32	11		5			32		44
Union	32				6		2	10			9	4		34		30		
Keystone........	34										11		3	10	3	4		
Ohio	32		11		6						11		2	8	2	6		
Washington ...	38				6			32			11		2	8		24		

The arrangement of these furnaces is on the plan of the one previously figured. The lines, it will be noticed, show a remarkably flat bosh. This is more noticeable in older furnaces; in relining them, it has been usually the plan to make a sharper angle, and some of the most experienced men of the district state that the advantage of such a change is decided. In the table of capacities is given also the production of the furnaces, by which it will be seen that the average capacity of the charcoal furnaces using hot-blast is about seventy-five cubic feet per ton of iron made in 24 hours. The two cold-blast furnaces, Hecla and Jefferson, show such difference that no average can be drawn, but when with these figures for capacity the fuel consumption be taken, the relation between a proper volume and the yield is seen. Jefferson furnace makes a ton of iron with 171 bushels of charcoal, while Hecla requires 221 bushels to do the same work.

The capacity of some foreign and other furnaces is here given for sake of comparison.

These figures are from recent publications, and represent present facts. It is to be regretted that so few figures relative to American furnace practice are published in sufficiently detailed statements to be reliable for exact calculation. The idea that such matters are secrets, which should be kept from the public, is, however, getting to be a thing of the past. These charcoal furnaces are generally provided with from

one to three tuyers; in most of the smaller furnaces using cold-blast, a single tuyer is all that is used; this is the case in Hamden, Hecla and Jefferson furnaces.

Locality.	Blast.	Volume.	Daily production.	Cubic feet to ton.	Tons charcoal to ton.
Styria	Cold	452.	$7\frac{1}{2}$	60.2	....
Russia	"	3814.	19.5	201.	1.05
"	Hot	2295.	15.5	123.	1.60
"	Cold	1660.	18.0	85.	1.34
Sweden	Warm	3494.	21.5	162.	0.98
"	"	1427.	16.8	85.	1.19
"	"	3669.	15.0	244.	1.12
"	"	1182.	12.7	85.	0 97
Pine Grove Furnace, Pa		1000.	16.9	59.	1.17

Where the blast is heated, as is the case in many of the charcoal furnaces, the heating apparatus consists of a pipe-stove, having either horizontal or vertical pipes, as shown respectively in either the Wasserhalfingen or Player patterns; these stoves are placed on the bank of the furnace, and generally heated by the gases which have previously passed under the boilers, an arrangement shown in Figure II.

The blast temperature in charcoal furnaces is usually not high. The furnaces are distinguished by cold-blast, warm-blast and hot-blast; the warm-blast being an indefinite quantity, extending to a temperature that will melt zinc or higher; the exact temperature of blast used, though registered by so-called pyrometers, is rather a matter of conjecture than knowledge; the faulty construction of the instrument preventing any very great reliance being placed on their indications. The furnace men usually report the temperature of the blast from seven to eight hundred degrees Fahrenheit.

As to the details of construction of these furnaces, the stone stack has already been alluded to; these stacks are built of the carboniferous sandstone, and are most of them quite old, as will be seen by the dates attached to the table of the works on pp. 456-58. The expense of such stacks, compared with the more modern and lighter iron mantle, would preclude their being built at the present time. The only charcoal furnace built with an iron mantle in the Hanging Rock region is the

"Monitor" furnace, four miles from Ironton, the mantel being supported by iron pillars, so arranged as to allow freer access to the tuyers.

The hearths are mostly built of sandstone, and the upper lining of the furnace, of fire-brick. The sandstone for the hearths is found in abundance in various places in the carboniferous beds. The stones under Coal No. 4, under the gray limestone, between the block ore and ferriferous limestone, and from other localities, are reported as used at different furnaces. These stones being easily worked, and very refractory, wear well. The fire-bricks for lining are obtained from various manufactories in the district, or from several of the well-known firms of Pennsylvania and the east. The tuyers in the cold-blast furnaces are generally simple iron nozzles not protected by water; wherever the blast is heated at all, the ordinary coil-pipe or plain iron water-tuyer is used; the diameter of the tuyers in the cold-blast furnaces is generally from 3½ to 4 inches. The blast pressure is low, usually from 3 to 3½ pounds or a little higher in the hot-blast furnaces.

Many of the furnaces are provided with blowing-engines in which the steam-cylinder is connected with the blowing-cylinder by means of gearing or large cog-wheels, so arranged that the steam-cylinder makes from 1½ to 2 strokes for each stroke of the air-cylinder; actual numbers are 17 of the steam-cylinder, 8½ of the air-cylinder; 18 steam-cylinder, 12 air-cylinder (strokes per minute). The steam-cylinders are 18 to 20 inches in diameter, the blast-cylinder is 44 in. by 5 ft., 48 in. by 6 ft., 36 in. by 4 ft. These figures, taken from furnaces in blast, serve to indicate the average. The tuyer is generally set in the hearth at from one-half to two-thirds its height; the deep hearth being rather characteristic.

The furnaces being bank furnaces, no hoist is usually required. In some cases, as at the "Grant" furnace at Ironton, a water-hoist is used, consisting of a wooden tower in which the elevator runs suspended by wire cables; the arrangement for raising and lowering consisting of a tank placed in the bottom of each of the two cages, and so arranged that when the cage is up, this can be filled with water lifted by a pump through a connecting pipe. The increase of weight thus given brings down the empty cage, and lifts the full one; on reaching the bottom the tank empties automatically through an opening in the bottom, which is closed by a valve connected with a stem, which opens it when the cage is down. These old water-hoists are curiosities in the way of fur-

nace equipment, and give rise to some trouble in cold weather from the tendency to freeze, and in this way clog and interfere with the running of the hoist. Simple water-hoists are found at some other furnaces in the State, and will be alluded to further on.

The hearths of the furnaces are built, some of them, with a wide fore-hearth, which is closed by a dam and plate exactly as will be found described in "Truran," on the Iron Manufacture of Great Britain, or in all the older standard "Treatises" on "Metallurgy." In the more recently lined furnaces the dam has been placed nearer the tymp or top of the arch, over the opening into the bottom of the furnace, and the wide fore-hearth has been gradually abandoned; the loss of time at each casting, due to the necessity of replacing the tymp-stone and cleaning the hearth is considerable, this operation taking from 1 to 2 hours.

A curious fact in regard to the working of these furnaces of the Hanging Rock region is, that almost without exception work is suspended during Sunday, the furnaces being stopped at 12 o'clock Saturday night, the blast being turned on again at 12 o'clock Sunday night. It is claimed by the furnace men in the district that not only is this no disadvantage, but in the long run advantageous, as it secures them a better class of labor and more command over their men. Each of these charcoal furnaces is of necessity provided with large sheds, placed near the furnace and of a capacity of in some cases 400,000 to 500,000 bushels of charcoal. The danger of storing charcoal in large amount is the risk of fire, a rather serious one, as these charcoal houses have frequently been destroyed in this way, entailing of course great loss. As to the effect of storage on the charcoal, it is stated that it works rather better when taken from the storehouse than when worked direct from the wagon load, the reason assigned being that the charges are more uniform, owing to the mixture of the material, which being loaded into the stockhouse is drawn from what represents the average quality, whereas different wagon loads differ enough among themselves to affect the relation between the fuel and ore, and consequently change, though perhaps only slightly, the working of the furnace. The greater or less dampness of the charcoal produces some effect, but owing to the universal custom of measuring rather than of weighing the charges, does not change the ratio of fuel to ore. But even here it is stated that when wagons come in damp from rain, it is necessary to "lighten the ore burden;" that is, diminish the amount of ore to a bushel of charcoal.

The number of men employed around these charcoal furnaces is from 14 to 20.

The method of removing slags from the furnace is usually to allow the slag to run over the top of the dam continuously after it has reached that level. From its acid and viscid character it runs out in thick, pasty masses or streams for a short distance from the furnace ; it is then caught by an iron grapnel, drawn away from the furnace, then broken up and carted off.

The grapnel is attached to a chain, which is wound around a drum worked by a man-power arrangement, consisting of a large wheel 8 or 10 ft. in diameter, provided with spokes or pegs, which a man treads like a continuous ladder—a prime mover more characteristic of the 15th than the 19th century.

The charcoal furnaces are mostly built with an open top, or, rather, with a simple conduit, by which the gases are conducted to the boilers, and the ore is charged through an opening in the side of this channel; the number of charges is regulated by the speed with which the stock descends, its level being ascertained by inserting an iron rod and thus measuring the depth. The fluxes used are charged with the ore, the charcoal charge, separately.

The throat of the furnace is usually bright or burning, which, with its extremely contracted character, may possibly partly account for the large amount of charcoal used in these furnaces.

The iron produced at most of these charcoal furnaces is of a high grade, the cold-blast furnaces producing car-wheel iron of a wide reputation. The following analyses will indicate the character of some of the principal irons:

	1	2	3	4	5	6
Graphite	3.358	3 75	3.645	undet.	undet.	3.245
Coniferous carbon	.620	.12				
Silica	.433	3.92	1.045	.766	2.795	2.330
Sulphur	.024	.04	undet.	.027	.068	.037
Phosphorus	.340	.521	.422	.251	.302	.619
Manganese	.581	undet.	.616	undet.	undet.	.720

1. Hecla iron No. 3—Chemists, Chauvenet & Blair.
2. Washington Furnace—Chemist, Loomis.
3. Hecla No. 3—Chemist, Prof. Dudley.
4. Vesuvius No. 1—Chemist, Gill.
5. Pine Grove Furnace—Chemist, W. D. Wood.
6. No. 1 iron, Hamden Furnace (analyzed for the Survey).

Some of the analyses were furnished by furnace companies, and are by well known chemists, whose names are appended to the analyses and are a guarantee of their accuracy.

One of the most valuable qualities of this car-wheel iron is its property of chilling, or becoming white and hard when suddenly cooled, as when cast against a cold metal surface. Where such iron is made, it is generally cast in a chill bed or series of gutter-shaped moulds of cast-iron; this develops the white, hard layer in the pigs. The iron is then graded by number according to depth of chill and character of grain, as shown on the fresh fracture. This chill may run from being barely perceptible in No. 1 to two-thirds the depth of the casting in Nos. 4 or 5.

Iron is graded thus at each furnace as it is made; there is, however, little correspondence between the analyses of the metal and the difference of grade, as the following analyses will show. They represent irons of different number made at the same furnace, and with the same mixture of ores, etc.; only the amounts of silica and carbon are given, the amount of phosphorus not being subject to variation, unless the ore changes, as all present finds its way into the iron.

	1.	2.	3.
Carbon	3.24	3.43	3.15
Silicon	2.33	2.33	3.85

Lord, *Chemist.*

1. Gray No. 1 iron from Hamden furnace.
2. No. 2 iron from Hamden furnace.
3. Silver Gray iron from Hamden furnace.

All are made from gray limestone ore with charcoal. No. 3 shows the cause of its silvery character in the high silica percentage. The slags produced in these furnaces are acid silicates; they are illustrated by the following analyses, made in the laboratory of the Survey:

	1.	2.	3.
Silica	52.92	53.71	49.37
Alumina and oxide of iron	22.24	22.94	22.49
Lime	21.51	20.67	26.14
Magnesia	1.93	2.09	1.95
Oxide of manganese	1.66	undet.	not det.
Sulphur	0.16	0.19	0.29
Phosphorus	none.	none.	none.

These slags are from Hamden furnace, and accompanied the No. 1, No. 2 and silver gray iron, respectively.

The silvery irons made in this district owe their peculiar character to high percentages of silicon, which gives the light color and greasy lustre, sometimes so strongly marked; occasionally such pig-irons reach unusual percentages in silicon, one from Star furnace at Jackson, showing 6.62 per cent. of that element. The silica or silvery pig commands a ready sale for foundry purposes, serving as a softener in mixtures; for making wrought-iron it is, however, nearly useless, as it causes great destruction of fix or ore lining in the puddling furnace.

A peculiar kind of white iron in large crystals has been made from time to time at various points in the Hocking Valley and Hanging Rock districts. It was sent to the University laboratory as possibly spiegel iron. Analysis showed that it owed its peculiar properties to excessive amounts of phosphorus.

Of this character was the iron made at Mt. Vernon furnace from what was locally known as the "Hallelujah ore." The iron was in large crystals of a tin-white color; it was hard, but not so hard as ordinary white iron; it was extremely brittle, being easily pounded to powder, and could be broken from the pig in flakes with a hand-hammer. This iron showed 4.30 per cent. phosphorus; it was low in silica and carbon, being almost a phosphide of iron!

The ore (Hallelujah ore), from which it was made, showed on analysis 2.14 per cent. of phosphorus.

As stated before in this report, a quite similar iron was made from the ore deposit near Moxahala furnace.

These very highly phosphorated irons are interesting rather from a metallurgical than a commercial point of view; still they find a market, being used to some extent as softeners in foundry mixtures. The introduction of the basic steel process would open a wide field of usefulness for these irons. It is possible that trial has been made of them for this purpose, as Mt. Vernon furnace has lately found a special market for quite a quantity of this metal.

Taking the average of the above analyses, the formula of the slag shows it to be a bisilicate or one containing half enough base (lime and alumina) to saturate the silicic acid. The character of the slag corresponds to this formula; it is glassy and thick, and solidifies slowly.

The iron is unusually high in silicon for a charcoal iron, probably because the slag is so high in alumina, compared to the lime and silica, as to give it a refractory character and necessitate too high a temperature in the furnace. The effect of much silicon appears to be to injure or destroy the chilling property of the iron.

The only methods of utilizing the gases of the charcoal furnaces are those described and figured in connection with Howard furnace, Figure II. This method is perhaps as well adapted as any to the small amount of gas produced in these furnaces, though the large amount of fuel used will result in the production of more gas than is usual in charcoal smelting. To make an estimate of the actual amount of gas produced, it is necessary to know the composition of the charge, the fuel and the iron produced. Calculations, based on the charges already given, and restated here for reference, may be made, and will give approximate results. Exact results as to amount of gas and blast could only be obtained on knowing the composition of the furnace gases. In default of this a fair average composition will be assumed, making due allowance for the large amounts of fuel used in these furnaces, the effect of which will be to largely increase the ratio between the carbonic acid and carbonic oxide in the gas.

The charges referred to represent the working of one of the best charcoal furnaces of the Hanging Rock region. The analyses were taken from the furnace records in most cases, and represent well averaged samples:

Ore (limestone).	Average.
Sesquioxide of iron	62.30
Alumina	7.86
Silica	22.14
Lime	3.09
Manganese	0.85
Magnesia	0.92

WEBER, *Chemist.*

Limestone.	
Carbonate of lime	95.65
Carbonate of magnesia	.19
Alumina and iron	2.70
Silica	1.20

Slag.	
Silica	54.68
Alumina	20.63
Lime	23.71
Oxide of iron	0.32

WEBER, *Chemist.*

Iron—Average.	
Carbon	3.50
Silicon	2.00
Phosphorus	.36
Iron	94.00

Average charges extending over six weeks, taken from charging books:

Pig-iron per day, 17.5 tons of 2,000 lbs.
Limestone per ton iron, 0.365 tons, or 730 lbs.
Charcoal per ton iron, 1.419 tons.
(Charcoal weighed, and including 11 per cent. "brands.")
Ore per ton iron, 2.175 tons.

Of the analysis above given, the limestone and slag are from the furnace; that of the pig-iron represents the average composition, as shown by analyses published in this report.

The analysis of the ore is one made by the present Survey of the same ore in a neighboring locality, and represents fairly the average.

The blowing engine had 2 cylinders of 48x50 inches, and these made an average of 11 strokes per minute. The blast pressure averaged about 3 lbs. The temperature of blast about 800°.

The amount of carbon in the fuel may be assumed at about 90 per cent., the other 10 per cent. being moisture and ash. This estimate is based on the mode of making and storing charcoal for use, which easily allows the absorption of this amount of water.

One ton of pig-iron contains 94 per cent of iron, or 1,880 lbs. This is derived from the 2.175 tons of ore used, and represents a yield of 43 per cent. on the ore.

The quantity of slag produced in making a ton of iron may be ascertained as follows: 4,350 lbs. of ore minus 2,688 lbs. of iron oxide (corresponding to the iron above), leaves 1,662 lbs. of slag-forming elements in the ore. The 730 lbs. of limestone contain 95.84 per cent.

carbonates of lime and magnesia, and 4.16 per cent. silicious matter and alumina, or in pounds furnished to the slag. There is as follows:

Silicious matter of limestone	30.4 lbs.
Lime and magnesia of limestone	389.1 "
Total from limestone	419.5 lbs.
" ore	1662.0 "
" fuel (1.5 per cent.)	42.6 "
Total slag forming materials	2124.1 lbs.

Deducting the silica, etc., absorbed by the iron ($2\frac{1}{2}$ per cent.), it appears that for each ton of iron made the furnace makes about 1.05 tons of slag.

Owing to the hot throat of the furnace, and the short stack, it is probable that all the carbonic acid expelled from the limestone is converted into carbonic oxide. Assuming this to be the case, and also that about one-third the carbonic acid produced from the reduction of the iron ore by the gas is similarly reduced, the following account may be stated:

Carbon in fuel per ton iron made (2.808 lbs. × .90 per cent.) = 2.554 lbs.	
Carbon required to reduce 304 lbs. carbonic acid in the limestone	83 lbs.
One-third carbon required to reduce the carbonic acid from the ore reduction	201 "
Carbon lost in going through the furnace	284 lbs.
Carbon in iron (3.5 per cent.)	70 "
Carbon to be deducted from the fuel used	354 lbs.
Or carbon actually burnt at tuyeres	2200 "

To burn this amount of carbon to carbonic oxide, 2933 lbs. of oxygen, or 176,000 cubic feet of air nearly, would be required at normal barometer and temperature.

This then is the amount of blast needed to make one ton of pig-iron. To compare this with the blast engine record, it appears that one ton of iron would be made in $\frac{1}{17.5}$ day, or 82 minutes.

The capacity of each blast cylinder is 52.4 cubic feet nearly, or of the two about 104.8 cubic feet; hence this amount of air is taken in to the blowing apparatus at each stroke. Assuming 11 double strokes per min-

Number.	Stove.	Number of pipes.	Blast engine.		Strokes air cylinder.	Temperature of blast.	Days run.	Charge and product.			
			Blast cylinders.	Steam cylinder.				Charcoal, bus.	Ore, lbs.	Limestone, lbs.	Tons (2,000 lbs.) iron made.
1			3′x4′		26	Cold.	183	606,210	17,284,500	1,100,000	2,744.00
2			44″x5′	18″	8½	Cold.	½ (12 hrs.)	957	24,650	2,900	5.60
3	Player	18	54″x5′		14	800°	7	17,920	596,050	93,980	134.94
4	"	24	48″x6′	18″	18	900°	62	128,837	4,792,410	330,610	1,015.00
5	"		4′x44″ 2 cyls.		9x12	817°	41⅞	2,086,106 lbs. 90,700	3,198,061	536,700	734.80

Number.	Kind of iron.	Hearth.	No. of tuyeres.	No. men employed to run.	Tons ore per ton iron.	Tons charcoal per ton iron.	Bushels charcoal per ton iron.	Tons limestone per ton iron.	Tons iron made per day.	Capacity of furnace, cubic feet.	(Ton per 24 hours, 2,000 lbs.), cubic feet per ton iron.
1	Foundry.	Sandstone.	1	16	3.145	2.54	221.0	0.200	15.0	1,137.7	75
2	"	"	1	14	2.200	1.96	171.0	0.258	11.2	2,364.1	122
3	"	"	2	20	2.207	1.52	132.7	0.348	19.3	1,634.7	84
4	"	"	1	16	2.360	1.46	126.9	0.163	16.3	1,052.7	64
5	"	"			2.175	1.48	123.0	0.365	17.5	1,229.4	70

NOTE—Ore all native and no mill cinder used. The tons of charcoal, except in case of number 5, are approximate and calculated from the measured amounts on the basis of 23 pounds to the bushel, including brands.

ute, the blast taken in 82 minutes will be that given by $22 \times 82 = 1804$ strokes; and allowing 104.8 cubic feet to the stroke, there results 189,000 cubic feet of air per ton of iron made, calculated from the capacity of the engine.

The exact number of strokes of the engine is, of course, not a matter easily ascertained, and hence the above is only an approximation as far as the engine calculation is concerned, but it serves to show the manner of calculation; if the analysis of the gas is made, the calculation controlled by the actual amount of carbonic acid in the gas, becomes exact on all sides. Knowing the blast entering the furnace, the gases can be closely calculated in volume; 176,000 cubic feet of blast would furnish about 211,000 of gas. The weight of this gas can be also exactly found, and will be given further on.

The working of these charcoal furnaces, in regard to economy of fuel and yield of ore, may be illustrated by the following table, the figures for which were taken from the books of the companies. It will be seen that the consumption of fuel for the ton of iron produced is from 220 to 123 bushels. These furnaces represent all varieties of outline and temperature of blast.

The following table was kindly furnished by a charcoal furnace company at Ironton, Ohio, and gives results extending over a number of years, and is here inserted as of interest:

Year.	Tons per day.	Tons made.	Average ore per ton.	Bushels charcoal per ton.
1866	$11\frac{8}{16}$	2,332	2.28	$1.55\frac{5}{8}$
1867	13.91	2,685	2.35	1.42
1868	$12\frac{1}{3}$	2,049	2.38	1.38
1869	$12\frac{1}{2}$	4,011	2.38	1.42
1870	13	2,899	2.68	1.48
1871	12.65	2,778	2.28	1.43
1872	$12\frac{1}{4}$	3,219	2.24	1.53
1873	12	2,634	2.53	1.69
1874	$16\frac{1}{6}$	3,083	2.58	1.46
1875	$14\frac{3}{4}$	2,978	2.57	1.43
1876	15.03	3,081	2.75	1.45

It will be seen that the consumption of charcoal in the Hanging Rock region is large. The reasons for this may be found in several causes—the imperfect roasting of the ore, the low grade of the ore, and the dimensions and lines of the furnaces. The furnaces of the Hanging Rock region are short, and probably promote the escape of gases overcharged with carbonic oxide. To investigate this matter the analyses and figures given before will be used as a basis for a calculation of the heat requirements and fuel consumption of the furnaces. Analysis of the gas would be necessary to settle the questions involved, but a partial examination may be made as follows: referring to the former calculation, 1 ton of pig-iron containing 1,880 pounds metallic iron was made with about 2,250 pounds of carbon; of this 70 pounds went into the iron, leaving 2,180 pounds as fuel, from the combustion of which the heat of the furnace is maintained, with the addition of what heat the blast supplies.

The heat requirement of the furnace does not admit of exact calculation, but it can be approximately determined per ton of iron as follows:

(*A.*) Reduction of iron ore: This has been carefully investigated by Bell, Gruener and others, and the accepted result may be taken at about 1,800 units per unit of iron, or for 0.94 of a ton, 1,692 units, the unit taken being the heat required to heat one ton of water, 1° centigrade; this ton unit will be used to avoid large numbers, the relation being the same, whether the ton or pound be used.

(*B.*) The heat required in fusion of iron and slag: The heat represented by a unit of iron, at the temperature of the furnace, is determined by Bell and others to be about 330, and by a unit of slag, 550. This gives—

For 1 ton of iron	330	units.
For 1.05 slag	577	"
Total	907	"

(*C.*) For reduction of silicon, manganese, etc: The expulsion of the carbonic acid from the limestone, and the evaporation of 8 per cent. of water from the charcoal, will require a total of 650 units.

(*D.*) The loss through walls of furnace, etc., will be smaller than in the iron mantle furnaces, but assuming the figures found for such

furnaces, as applying here, this item would be about 300 units. The account thus stands:

A	1,692
B	907
C	650
D	300
Total	3,549

There is one more item, large and unsettled in this case—the heat carried off as *sensible heat* in the gases. Calling this X, we have the total heat requirement of the furnaces $= 3{,}549 + X$ for each ton of iron made.

To calculate X, the temperature of the gas need be known, which in the present instance could not be ascertained. The throat of the furnace is a bright red, however, and hence this could not be less than 600° centigrade. On this assumption a value of X would be obtained as follows:

The blast required per ton of iron was before calculated at 176,000 cubic feet, equal to 6.379 tons. The gas produced would equal in weight this amount plus the carbon in the limestone and fuel, and the oxygen in the ore and carbonic acid of the limestone. The total weight of gases would then be per ton of iron, after adding these items, 8.300 tons. This is large. The amount of the gases in the Cleveland blast furnaces (England) is from 6 to 7 tons per ton of iron. Taking the mean specific heat of the gases at 0.24, the heat required to raise them to 600° centigrade would be $8.300 \times .24 \times 600 = 1{,}194$ heat units, making the total heat requirement $3{,}549 + 1{,}194 = 4{,}743$.

Of the sources of heat the blast (6.379 tons at a temperature of 500° centigrade) would give about 750 units, leaving in round numbers 4,000 units to be accounted for from the fuel. This fuel first burns at the tuyeres to carbonic oxide, and gives in so doing 2,400 units per unit of fuel. We may first assume that all the carbon, except that required to decompose the carbonic acid of the limestone, reaches the tuyeres; there would be 1.235 tons then burned; $1.235 \times 2{,}400$ gives 2,964. Again, part of this carbonic oxide is burned in the upper part of the furnace by the oxygen of the iron ore into carbonic acid, and gives for each unit of oxygen so used 4,200 units of heat, but 0.94 ton

of iron represents 0.402 tons oxygen. This would, by the above combustion, furnish 1,688 heat units; adding to this the 2,964 produced by burning at tuyeres, we get, under this assumption, 4,652 units, an excess of 652 heat units over what is required to make the iron.

Too many figures are lacking to draw exact conclusion from the above discussion, but certainly this much appears, the high temperature at which the gas escapes from the top of the furnace is one great source of heat loss, and is accompanied, as the last figure shows, by a failure to even closely realize the true working of the furnace, in which the carbonic acid formed by the reduction of the ore escapes from the furnace without reduction. The 600 units of heat excess above calculated would mean, that this amount of heat was absorbed by the reduction of carbonic acid by carbon. The exact amount could only be properly calculated by working from analyses of the gas. The heat requirement above given is excessive, as all amounts were made large to cover doubtful knowledge; probably a closer computation would show more striking differences and a larger waste of fuel still.

But while the amount used is in excess of what ought to be needed, it is also evident that the actual requirement is very large. This is due to the lean mixture, which necessitates a very large amount of slag and a consequent increase of fuel, which means more blast, and thus more air and gas to heat.

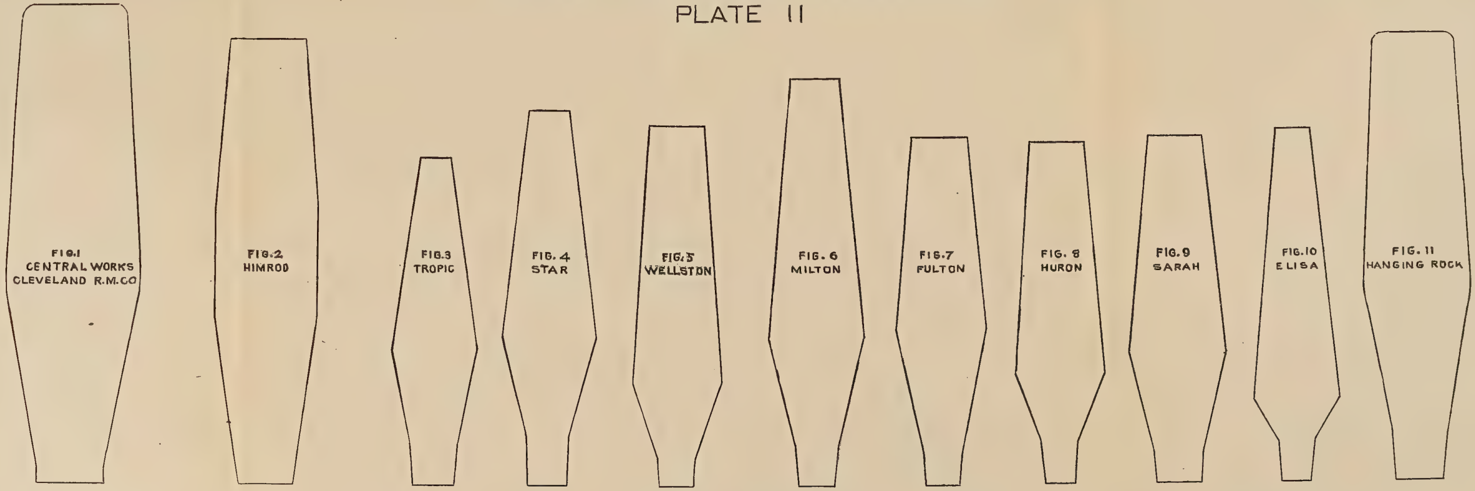
Raw Coal and Coke Furnaces.

The best iron smelters are beginning to recognize that there is but little reason in adopting different outlines for coke and for raw coal furnaces, especially in the lower part of the furnace; hence, these furnaces will be described at the same time.

The furnaces using these materials are distributed through the different districts, as indicated by the special description of each district and by the table of furnaces. They present much greater variety in equipment and construction than the charcoal furnaces; they show progressive changes in outline, which are of interest in showing the growth of the knowledge of the true principle on which furnace construction should be based. An endeavor has been made to obtain the outlines and results of the working of the more typical furnaces throughout the State.

COAL AND COKE FURNACES.

PLATE II



Those at Ironton have been already mentioned. These furnaces are entirely lined with fire-brick, and generally the lining is made of shaped brick, each brick being fitted to its place, making in this way a more expensive but more durable lining.

Plate 2 annexed gives the lines for some of the newest as well as some of the oldest coal and coke furnaces in the State.

The capacities in cubic feet, daily production and yield per cubic foot for the same furnaces is given in the following table:

Name of Furnace.	Capacities in cubic feet.				Production in 24 hours (tons).	Cubic feet per ton.
	Shaft.	Bosh.	Hearth.	Total.		
Clevel. R. M. Co., Central Furn...	9,369	5,620	707	15,696	200	78
Himrod	3,254	2,886	2,534	8,674	48	180
Tropic	1,676	1,035	149	2,860	17	168
Star	2,730	1,163	193	4,086	18	226
Wellston	3,354	703	84	4,141	22.6	183
Milton	3,412	1,270	147	4,829	24.0	200
Fulton	2,470	1,259	101	3,830	16	239
Huron	2,955	1,098	118	4,171	15	278
Sarah	3,019	1,266	141	4,426	31	143
Eliza	2,488	373	109	2,970	17	174
Hanging Rock	4,869	2,522	331	7,722	....	....
Akron	4,300	2,946	....	7,246	....	....

The Akron furnace is not figured on the plate referred to. The capacities above given for it are calculated from the lines at present being built; it has no angle between the hearth and the bosh; it is 58 feet 10½ in. high, 10 feet at the throat, 16 feet in the bosh, and 7 feet at the bottom of the hearth. The tuyeres centers 54 inches above the sole.

The above table of course only shows a small number of the furnaces of the State, but includes about all the varieties of lines. The Central furnace, Himrod furnace, Akron furnace and Hanging Rock furnace represent the newest furnaces built in the Mahoning and Hocking Valleys and the Hanging Rock region; the others show the older practice.

The Mahoning Valley furnaces represent as a rule the newest and largest plants. Their location and general dimensions have been already given. To show the recent improvements and the general arrange-

ments in such furnaces, the new Central furnace of the Cleveland Rolling Mill Co. may be described.

This is one of the newest furnaces built in the State, and through the kindness of Messrs. Witherow & Gordon, of Pittsburgh, a drawing of the furnace has been furnished to the Survey; Fig. III shows this furnace. The following description of the details is also furnished by the engineer: "The furnace proper is 20 feet diameter of bosh, and 75 feet high; crucible, 10 feet diameter; and stack line, 16 feet diameter. The tuyeres are 8 in number, 7 inches diameter, placed 6 feet above the hearth level, made of phosphor-bronze, and project inside the crucible 12 inches. These tuyeres are secured in cast iron water-breasts of circular form, built in the brick-work, each one being coursed with a coil of 1 to 1¼-inch gas pipe. To these tuyeres are attached swing blow-pipes, constructed in such manner that the least amount of time is consumed in removing a tuyere, viz., the pipe is made in two sections, and is swung on trunnions, so that in no case need the pipe be taken down, but merely by loosening the keys and lifting the pipe on its trunnions, and clearing the space directly in front of the tuyeres ready for removing the same. These tuyeres are riveted to the cast-iron bustle pipe circling around the outside of the eight columns, which is 48 inches in diameter, lined with fire-brick to a clear opening of 24 inches. The columns are eight in number, of wrought-iron, and octagonal in shape, being 'Phoenix's patent. They are 25 feet high, 14 inches inside diameter, and ¾ inch thick, and support the mantle plate of the furnace, which is composed of three 15-inch rolled I-beams, circling entirely around the furnace. These columns rest on heavy cast-iron foundation plates. The bosh brick-work is protected with a series of cast-iron rings built in at intervals of 36 inches. Each ring is made in 16 segments, and each segment is coursed with 1¼-inch gas pipe. It has been found by practical results that these plates have effectually preserved the bosh for four years, at the end of which time the furnace was blown out, and the wall and plates were found to be in perfect condition, proving their efficiency. It will be observed that the bosh of this furnace is unusually high, and five of these rings have been inserted. They furthermore act in the capacity of binders. The entire crucible is surrounded with cast-iron plates, coursed with water, and attached to the dam-plate in front.

"The bell of this furnace is 11 feet in diameter, and is operated with

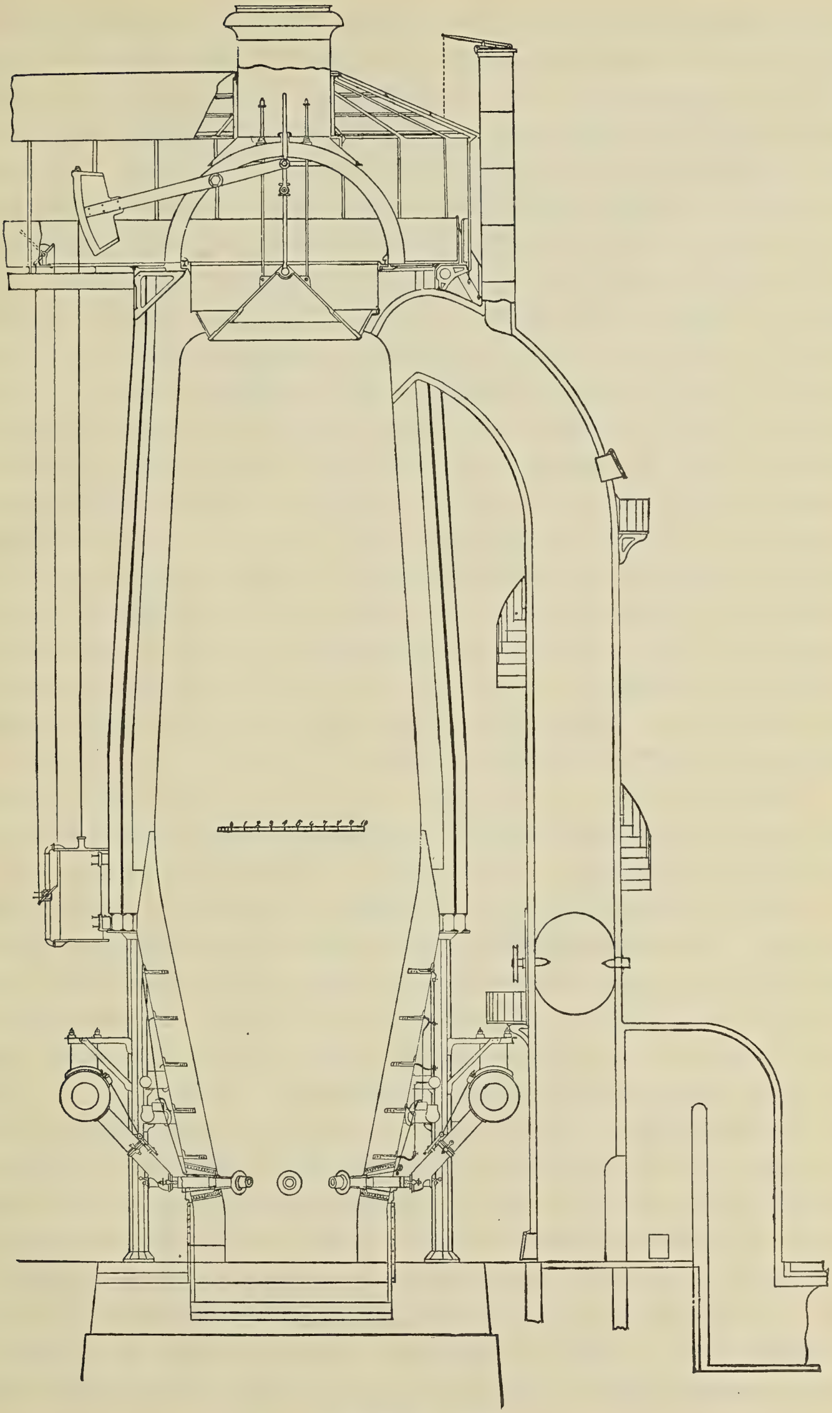


FIGURE III.

an air-lift. The hopper is of a cylindrical form, 14 inches diameter, in the lower part of which is placed the lip-ring upon which the bell closes. By this arrangement it will be observed we get a large area in the hopper, and do not encroach on the space around the platform for the easy manipulation of the charging buggies. Over this hopper is placed a cast-iron arch, upon which the hoisting lever is seated. To this bell are attached two safety-rods, which pass through the arch above mentioned, and have malleable iron handles attached to their ends. In case the main rod should break, these two rods would catch the bell before it could drop into the furnace. The down-comer is 7 feet in diameter, lined with fire-brick to a clear opening of 6 feet. On the bottom of this down-comer we have constructed an arrangement for catching dust. By this arrangement it will be observed the gas is forced to the extreme bottom of the down-comer, thence upward over a cross-wall built in this chamber, and thence downward to the flue under ground. By this reversed passage of the gases a great percentage of the dust is settled. This down-comer is provided with a winding stairway, so that in case the hoisting apparatus cannot be operated the top of the furnace can be reached in this way. We further provide for each one of these down-comers a butterfly damper, which is coursed with water, and built in the down-comer."

The other furnaces of the Mahoning Valley are built in respect to the mantel, tuyeres and general lines somewhat on the same arrangement. The coil, tuyere, or blow-pipes are in almost universal use.

At the Grafton Works at Leetonia, the tuyeres are made at the furnaces. The method of making these tuyeres is to coil wrought-iron pipe in a rather straight cone, the pipe being brought back on the outside of the coil; within this is set a cone of thin sheet-iron, and the whole is then set in a sand mold, and melted iron cast around the pipe, thus consolidating the whole into a solid block.

The use of a fore-hearth and dam in these furnaces is entirely given up, most of the newer furnaces being provided with a simple opening into the bottom of the hearth, somewhat conical, and possibly a foot wide by a foot and a half in height, through which the iron is tapped. The slag is removed from these furnaces by an opening below the tuyere, and situated either in front or on the side of the furnace. The advantages of thus closing the hearth of the furnace are the saving of time in casting, and the more regular working. The substituting of

thin walls in the hearth and boshes, which are protected from destruction or from over-heating by means of coil-pipes through which water flows, is very general, and is shown in the new furnaces of the Cleveland Rolling Mill Co. at its greatest development, and the probability is that this in some cases may be carried too far, some trouble having been experienced in some of the newer furnaces from the tendency to yield and crack from the pressure and heat of the charge.

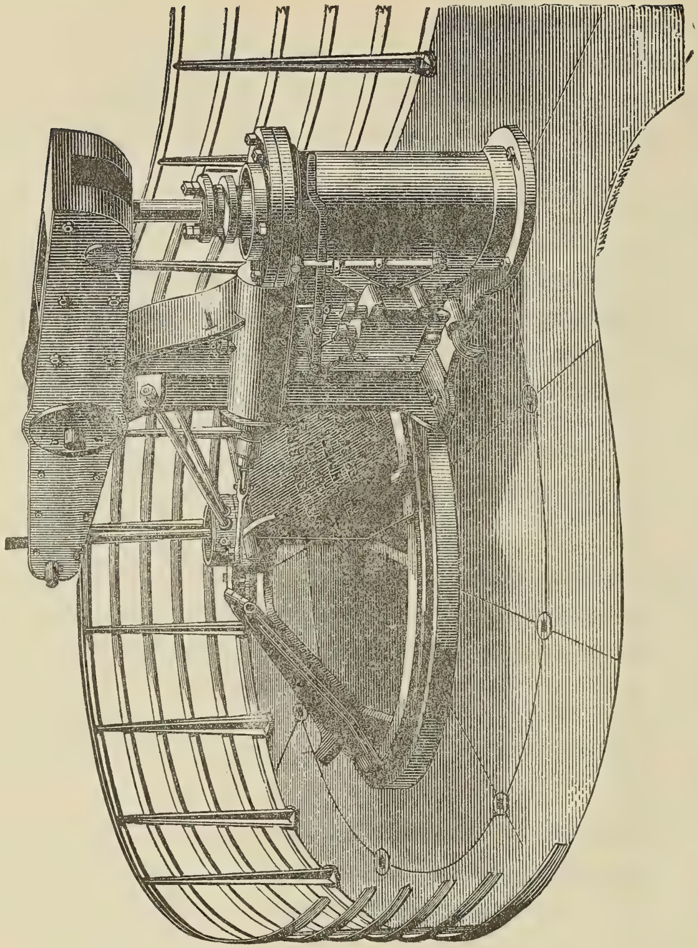
The arrangement of the upper part of the lining is practically the same everywhere, consisting of the interior of fire-brick separated by a narrow space from an exterior shell of common or red brick, placed next the mantle of the furnace; the space between the fire-brick and the red brick, as well as the space between the red brick and the mantle, is frequently filled with clay or sand, the object of these spaces being to permit the expansion of the lining when the furnace is heated.

In all these furnaces the lining of the shaft or upper part is supported by an iron lintel resting on iron columns; in the majority of cases these columns are circular, made of cast-iron and from 18 to 20 inches in diameter; the height of the columns, varying with the dimensions of the furnace, may run from 9 to 10 feet to, as in the case of the furnace figured, 25 feet, the more moderate dimensions being those usually found.

The substitution of wrought-iron riveted columns for cast-iron, found in some cases, gives more lightness with the same strength, an arrangement shown in plans of furnaces by Witherow & Gordon and the Weimer Machine Company, and other recent designs.

The foundation and sole of the blast furnace is masonry, generally carried down to considerable depth. The sole proper of the furnace is built of fire-brick of large size, and occupies a cavity in the stone foundation corresponding in diameter to the size of the furnace.

The way in which these bottom brick are set is usually on the plan of a flat inverted arch, being set obliquely from the sides in, and keyed by a cone-shaped central brick, the object of this arrangement being to prevent the bottom from lifting, which would certainly take place under an upward pressure produced by the melted iron around the brick. Sometimes the brick are made with angles, so arranged that each brick catches in the one next to it by a lug. In some cases the sole is made of sandstone instead of brick, where obtainable of good quality.



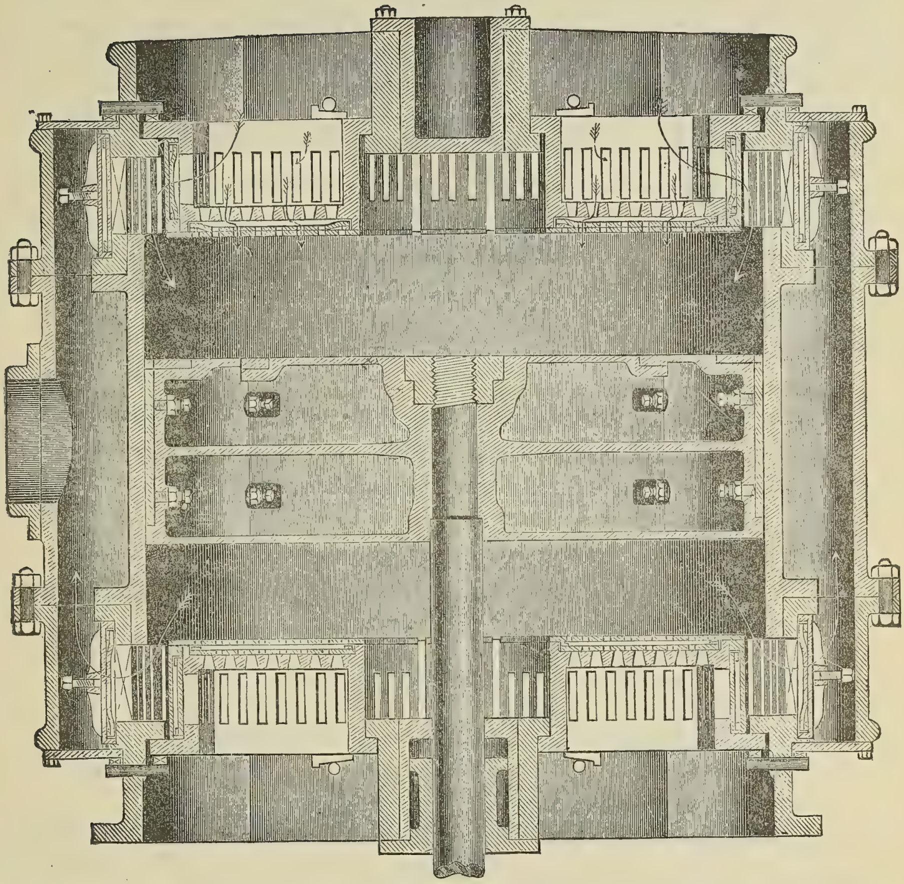
Charger, with Sliding Doors.

Weimer Machine Works Company, Lebanon, Penna.

FIGURE IV.

The method of taking the gases from the top of the furnace is almost invariably the simple plan of one or more openings in the side of the furnace, connected with a large wrought-iron pipe lined with fire-brick, and known as a down-cast or down-comer pipe. None of the more elaborate methods of taking gases from the center of the throat are in use in the State. The top of the coke and raw coal furnaces are invariably closed by a simple bell and cone, the same plan being used throughout the State. There have been until recently one or two furnaces at Massillon provided with a brick tunnel head and open throat; but the simple cup and cone is at present the universal practice. The methods of lowering the cone are in the first place, and most generally, a hand arrangement, by which the lever supporting the cone is raised and

Figure V



lowered by a crank motion, worked by a man at the top of the furnace. At some of the furnaces this is replaced by a steam cylinder which acts directly on the lever supporting the bell, and is controlled at the bottom of the furnace by a valve. Water is applied in almost every way for cooling and protecting the lower walls of the furnace; one plan in use at some of the furnaces of the Hocking Valley district is to surround the hearth-walls below the tuyeres with a sheet-iron ring or drum, the space between which and the furnace, possibly 8 to 10 inches in width, being filled with gravel and kept wet. The surrounding of the hearth by cast-iron plates, in which water circulates through coil pipes, is also considerably employed, as well as the bedding in the bosh walls, of flat iron plates similarly cooled, as in the furnaces of the Cleveland Rolling Mill Company.

The large "Etna" furnace, at Ironton, has the cone and cup covered by an arrangement of sliding doors, so fixed that after the charge is on, the cone and the space above it can be entirely covered, so preventing almost entirely the escape of gas from the furnace. This arrangement is similar to the one shown in Fig. IV, representing the sliding door charger, built by the Weimer Machine Works, at Lebanon, Penn.

The blowing engines are of the upright pattern, showing very little difference in detail, the direct action vertical engine being the one in most general use; recent improvement looking toward higher piston speed, have been introduced by machine works. One of the more recent patterns is shown, as to its arrangement of air valves, in Fig. V.

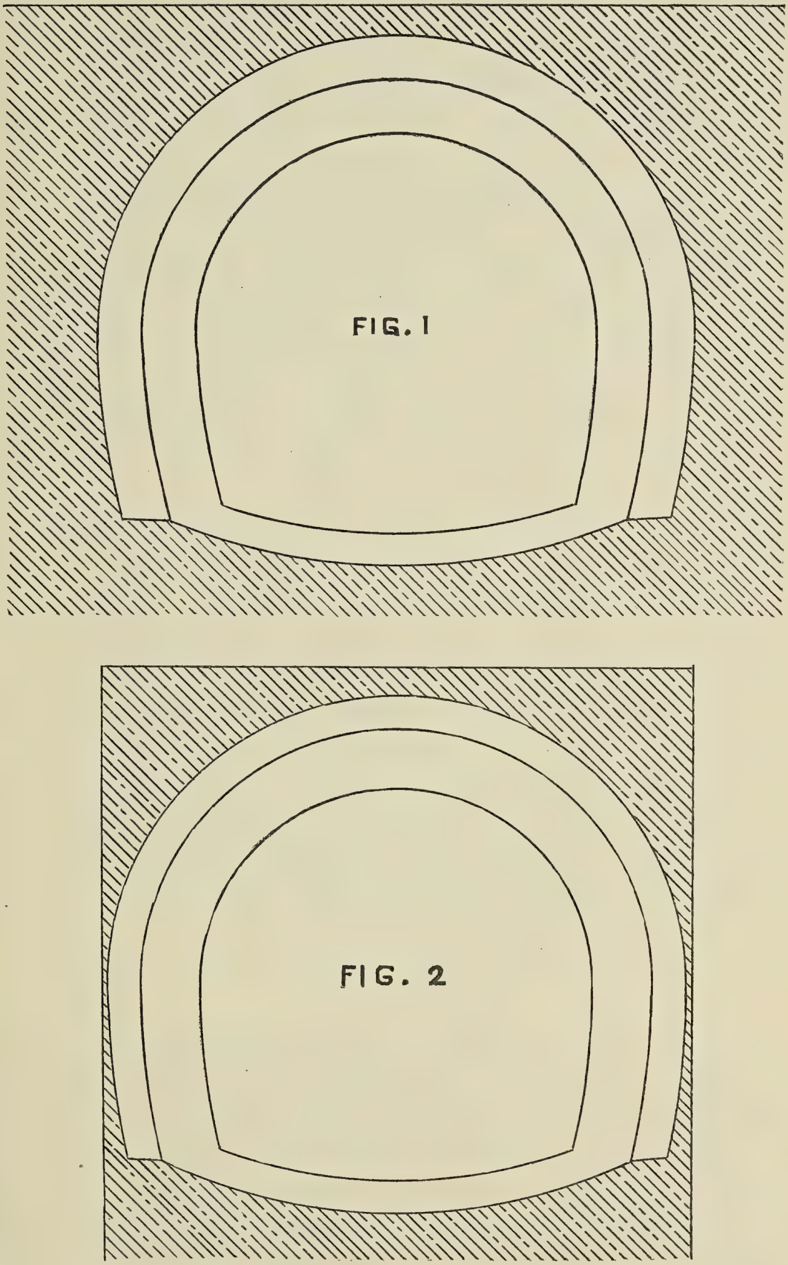
The object of this arrangement is to admit rapid action of the valves, and to reduce their travel or lift. As an illustration of the varying speed at which engines are run, the following figures may be of interest; the dimensions of the engine are also given for purposes of comparison:

	Cylinders.	Revolutions.
Himrod Furnace Co	84″x48″	40
Brier Hill	84″x48″	36
Wellston furnace	48″x48″	22
Eliza furnace	54″x48″	25
Hamden furnace	48″x72″	18
Pine Grove	48″x42″	9 to 12

It being probable that the working of a furnace is largely dependent upon the blast facilities, the tendency to the increase of power and speed of blowing engines is everywhere apparent.

The use and distribution of gas from the furnace follows at all the works the same general plan. In the cases of furnaces using much raw coal, the large amount of gas produced has led to its rather careless and wasteful use for heating purposes, also many of the furnaces using coke are in the habit of charging a certain amount of coal with coke, for the purpose of increasing the amount of gas. Where the coal is used in large proportion, the large amount of tar, water and dirt carried over by the gas necessitates the introduction of reservoirs or wells for the collection of this tar at the bottom of the down-cast pipe; these are sometimes above and sometimes below ground, the arrangement of the pipe consisting of a large expansion or drum of wrought-iron and ma-

FIGURE VI



sonry, terminating the down-cast pipe, a second pipe entering above the reservoir to carry off the gas. The arrangement at the Cleveland Rolling Mill furnace is shown in the drawing on page 523. The gases are distributed under ground through flues of various dimensions to the boilers and hot-blast stoves. Fig. VI shows the section of the flues at this furnace.

The boilers are generally cylindrical and proportionate in size to the engine and furnace; such boilers, however, being uneconomical of gas; in some of the Youngstown furnaces flue-boilers are being substituted. At the Himrod Iron Works this change is being made—boilers with two flues, replacing, the old cylindrical boilers, and each boiler also has an iron chimney. The manager states "that since this has been done they find that coke alone supplies plenty of gas, no coal being needed, and steam enough being furnished to run their large Weimer engine at nearly 40 revolutions per minute."

These Himrod works are particularly interesting, because they have introduced straight lines in the furnaces and large blast engines as a means of obtaining large production. Of their two furnaces, one in blast (15 feet in the bosh) made an average of 54 tons per day of iron, but on increasing the blast the production was run up to 66 tons per day, and consequently the blast capacity for the two furnaces has been increased largely. They have now three Weimer engines of 84 in. by 4 ft., 66 in. by 4 ft., and 60 in. by 4 ft., all three engines running on an average nearly 40 revolutions per minute, are used to blow one furnace. The company has, in addition, one horizontal "West Point" blast engine, 6 ft. by 6 ft., which runs about 25 revolutions per minute.

Hot-blast Stoves.

For the purpose of heating the blast various forms of stove are used, which may be grouped under two heads: the pipe stoves, in which the blast is passed through cast or wrought-iron pipes, heated by combustion of the waste gases of the furnace, fuel not being used for heating the blast directly; and the fire-brick or generator stoves, which work on the principle of passing the blast through a chamber filled with fire-brick or some similar material previously brought to a high temperature. Most of the older stoves are of the pipe pattern; of this kind there are many varieties in use, differing among themselves principally

in the form and dimensions of the pipes, the arrangement of the stoves themselves being practically the same in all cases. The gas being admitted with a sufficient quantity of air into a series of two or more arched chambers, 4 to 5 ft. high by $3\frac{1}{2}$ to 4 ft. wide; these combustion chambers connect through a series of flues or openings with a space above, in which the pipes which convey the blast are located, and the flame resulting from the combustion of the mixed gas and air circulates round the pipes which fill the chamber. The whole is built of fire-brick, and braced by iron tie-rods to prevent cracking and injury by heat. The blast does not go through one continuous pipe, but is subdivided, and passes through a number of pipes arranged in parallel order, the object being to diminish the amount of friction and consequently loss of pressure in passing through the stove.

In order to effect complete and proper combustion of the gas, air must be admitted with it, which is done by means of a jet, through which air is brought to the center of the gas flue, as in the compound blow-pipe. The simplest arrangement of pipes is that of a siphon or pipe bent on itself in the pattern seen in the old "Calder" oven, figured in books on Metallurgy. The large amount of room taken up by such pipes, together with the fragile character of the casting, has led to their universal abandonment, and many patterns are at present in use in this State, each supposed to present peculiar advantages, either as to durability of pipe, simplicity of construction, or ease in replacement. One of the best-known in the Mahoning Valley of these ovens is the "Hamilton" hot-blast stove, manufactured at Youngstown, and in use at several points there. Its peculiarity consists in having the pipes double and concentric, by which the air passes up through one pipe to the extremity of the enveloping pipe; this construction is shown in Figure VII.

The division of the air is well shown in this sketch, the blast passing into the stove through a long pipe or box, and dividing itself through the nine pipes connected therewith. The blast passes from one of these boxes or "bed-pipes" to the next, and so may be brought to a temperature only limited by the material and durability of the pipes. Another usual form of hot-blast stove has the pipes made in U-shape more or less united throughout their length by cross-bars; these are arranged in rows on two parallel "bed-pipes" in the stoves. Another form of stove has the blast-pipe section, a flattened oval divided through-

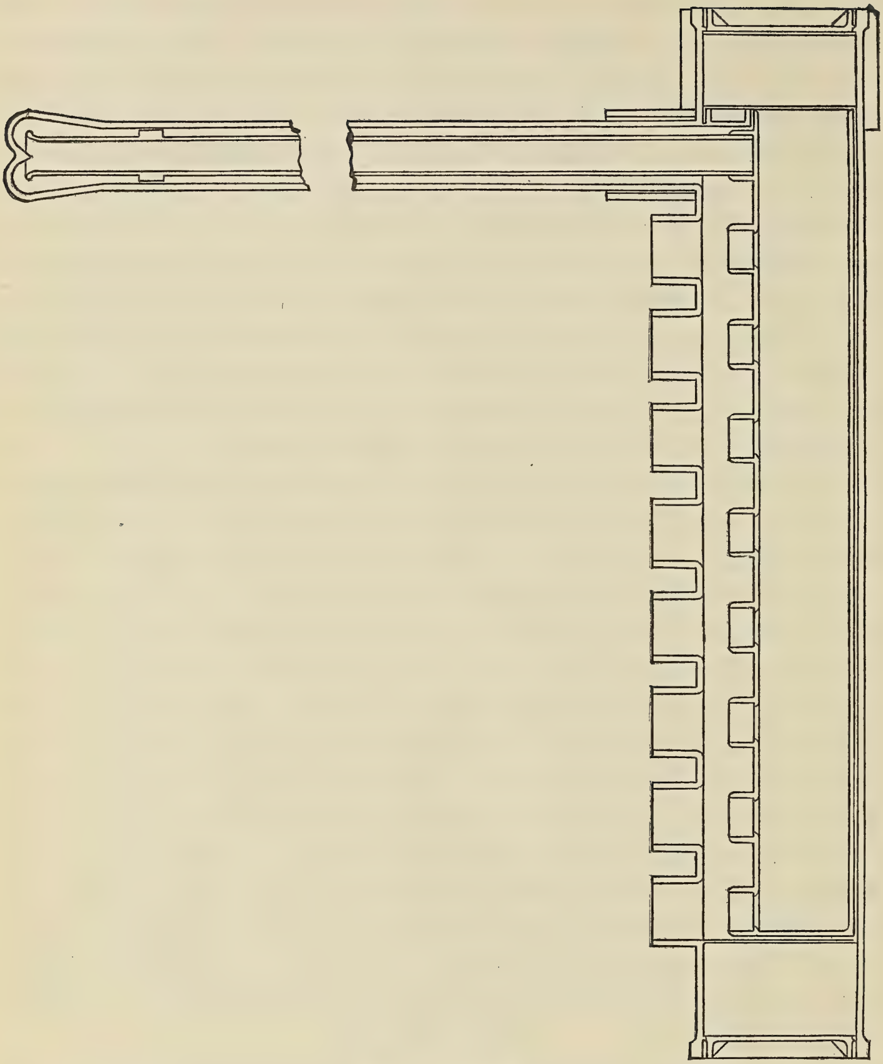


FIGURE VII.

out its length by a partition; the blast passing up one side and down the other; this stove being similar to the last in action and mounting. Various other details of construction are found, the stoves receiving special names from their manufacturers or the inventor of the pipe, as Pollock stove, Player stove, Hamilton stove, etc.

The Weimer Machine Co. built a stove in which the pipes, instead of resting by gravity on a "bed pipe," which serves to supply the current of air to the series of pipes, are suspended from the upper part of

the oven, and in this way take their blast from pipes arranged above instead of below.

The fire-brick stoves, represented by the "Cowper-Siemens" pattern, and the "Whitwell" stove depends on the principle involved in the regenerator steel furnaces.

If a large number of fire-brick be brought to a high temperature in a closed vessel, by allowing a mixture of gas and air to burn among them, and then, the supply of gas and air being cut off, the blast turned through, the heat of the fire-brick will be imparted to it. The Whitwell stoves, instead of using fire-brick piled in open order, as in the regenerator furnace, substitute parallel brick flues, through which the gas flames pass. Whitwell stoves are in use in several localities in the State; they have the advantage of great economy in gas, of great durability, there being no expensive pipes to replace, and of the power of imparting the highest temperature to the blast; any temperature in fact being attainable. They have the disadvantage of being comparatively expensive, at least two or more, usually three being necessary, as one must obviously be heating while the other is in use, and of requiring the attention of a person to change the blast from stove to stove. The regularity of the changes is important, owing to the irregularity in heat of the blast which will occur if it is improperly done. The older Whitwell stove is made short and of comparatively large diameter; the newer stoves are built higher and of much less diameter in proportion to their length. The number of angles over which the blast has to pass has also been diminished, and the number of flues increased. The new furnace of the Cleveland Rolling Mill Co. is provided with Whitwell stoves of the newest pattern, of which the following description is furnished by the designers: "The Whitwell stoves are 20 ft. in diameter and 70 ft. high, of the most recent type, and have a heating surface of 30,000 sq. ft. each. These stoves each contain 250,000 fire-brick, laid in the forms shown. Each stove is supplied with a cleaning crane, by means of which the stove coal can be cleaned in from three to four hours. The top is of a mitre form, and to this top are riveted a series of cast-iron doors, each of which gives access to a group of flues below, so that any part of the stove can be reached by the scraper. On each top is constructed a balcony, so that easy access can be had to these doors. The air is introduced into these stoves through an arch, which thoroughly diffuses the same. The gas is introduced through a circular

opening just above these flues, and is thoroughly mixed with the air in the first chamber, securing perfect combustion, thence passing up and down again through the first group of flues, thence up again and down to the chimney valve and flue. It is our object to have a thorough combustion of the gases in the first chamber, thereby utilizing the balance of the stove as a reservoir for heat. At a recent test made at the Isabella furnces, one of these stoves was kept on blast eight hours, giving an average temperature during this time of 1300 degrees Fahrenheit. The bricks used in these stoves are of a porous nature, so that heat coming in contact with them is readily absorbed."

This form of stove is figured in the transactions of the American Society Mining Engineers, vol. 9, p. 494, together with the older pattern of the same stove. These fire-brick stoves are in use in several places in Ohio, with generally good results.

While a full description of all the works in the State will not be attempted, short notice of some of the principal ones will be given, that the extent and character of the establishment, may appear, and any departures from the general statement given, be noticed.

The works at Cleveland comprise the furnaces of the Cleveland Rolling Mill Co., and the "Emma" furnace of the Newburg Furnace Co. This latter furnace has been recently overhauled, equipped with new hot-blast Pollock stoves, new boilers and a blast engine; the furnace, 66 ft. by 16 ft., is expected to make a hundred tons of iron per day; the furnace has 7 tuyeres, and is 8 feet in the hearth; it is run on Lake Superior ore and Brier Hill coal with Connellsville coke. The Cleveland furnaces use as a flux the Kelly Island limestone, of which the following analyis was kindly furnished by the Cleveland Rolling Mill Company:

Carbonate of lime	87.50
Silica	1.81
Alumina and iron	0.75
Carbonate of magnesia	9.75
Phosphorus	0.019
(Magnesia by difference.)	

The throat of the furnace is about 9 feet in diameter, but is considered too small, and it is proposed to enlarge it to a 12-foot throat in the future. The furnaces of the Cleveland Rolling Mill Co. are situated as follows: Two stacks at their mill at Newburg, one of the stacks only

being in use, and the other awaiting re-lining, the furnace making Bessemer pig-iron from the Lake Superior ores.

It may be of interest here to state that they consider the iron only fit for the converter, when the silicon is under 2.25 per cent. and the phosphorus under .12 per cent. No limit is assigned to the carbon.

The furnaces at Newburg are equipped with pipe stoves, similar to the Hamilton in design. The other stacks of this company are the two at their river works and the new central furnace just built, which was blown in about the first of October, 1882, but owing to some difficulty from the cracking of the bosh walls, had to be partly repaired, and the walls increased in thickness. At Youngstown are the two furnaces "Phoenix" and "Falcon," of Brown, Bonnell & Co., making pig-iron for the rolling mill; the two stacks of the Himrod Furnace Co., one in blast and the other about to be lined. This furnace is peculiar from its straight lines, and is figured on plate 2.

The furnace uses as a flux the Lowellville limestone, and is provided with a Pollock hot-blast stove, made with an oval pipe and central diaphram, as described under hot-blast stoves; also the furnace has four blast engines, three vertical and one horizontal; the furnace makes foundry and neutral mill iron, using the same mixtures for both. The Hannah furnace, of the Mahoning Valley Iron Co., is at the company's mill at Youngstown, and is running on a mixture of Lake Superior ores and mill cinder; the furnace is provided with 8 tuyeres and closed front, the slag being discharged through the back of the furnace, and not in front, as usual. The Hazleton furnace, at Hazleton, is about two miles south of Youngstown, on the Pittsburg, Ft. Wayne & Chicago R. R. The "Anna" furnace, at Struthers, recently bought by Brown, Bonnell & Co., has the usual pipe stoves and iron hoist.

At Lowellville the Mary furnace of the Ohio Iron and Steel Co. is an old stack, the hoist built with a wooden frame; the furnace works with a closed front, and is equipped with two pipe stoves of the Hamilton pattern, with a new one building of the oval pipe pattern. The present stack is 13 by 56 ft., $5\frac{1}{2}$ ft. in hearth, and 9 ft. in throat; provided with one engine, having blowing cylinder 66 in. by 4 ft. 6 in.; the furnace making at present 230 to 250 tons per week. It was stated that the furnace is to be rebuilt, refitted, and provided with an 84 in. by 4 ft. Weimer engine, and a 60-pipe Pollock stove. The new furnace is to be 75 ft. by 18 ft.; the furnace at present is provided with seven $4\frac{1}{2}$-inch

tuyeres; the blast pressure used is at present 3 to $3\frac{1}{2}$ lbs., and a temperature of about 900 degrees. The furnace at Girard had not been running for some time, but at present is blown in again. The Hubbard furnaces of Andrews & Hitchcock, at Hubbard, Trumbull county, are making foundry and mill iron from a mixture of Lake Superior, Canada and native ores. They are equipped with three blowing engines of 66 by 30 in., 84 by 35 in., 84 by 36 in., respectively, and make about 60 tons a day from each stack. The product for the year ending June 30, 1882, is 27,000 tons. The furnaces of the Brier Hill Coal and Iron Co., three miles northwest of Youngstown, comprise four stacks; they are provided with vertical blowing engines, using a blast pressure of 8 to 9 lbs.; the blast engines are 84 in. by $8\frac{1}{2}$ feet, with 36-in. steam-cylinder, running from 30 to 40 revolutions per minute. The furnace uses as a flux Lowellsville limestone, and is lined with Savage Mountain and Star fire-brick; the furnace is equipped with Thomas pipe-stove (a simple double-legged pipe), 36 pipes to a stove; the ore is almost entirely Lake Superior.

During 1882, about 5,000 tons of native blackband from Mineral Ridge were used. This company has a small Spiegel furnace, using Spanish ore; this Spiegel furnace has nearly straight lines, works with a closed front, and is blown by four tuyeres, is 45 feet high by $10\frac{1}{2}$ in the bosh.

The Eagle furnace, at Brier Hill, is an old furnace out of blast at the date of the Survey; it is built against a bank, but is provided with a short water-hoist, similar to the one described as in use at the Grant furnace at Ironton; the furnace has seven tuyeres, and is equipped with three pipe stoves. The Brier Hill furnaces discharge the slag from a small slag-tuyere at one side of the furnace front. The large Brier Hill furnace has nine tuyeres and a steam-hoist. The Niles furnace, at Niles, is at present run by the Arnold Furnace Company, and make a speciality of a soft foundry pig, under the brand of the "Arnold Iron." The furnace is a small one, provided with a wooden column water-hoist and pipe stoves.

In regard to the working of the furnaces in the Mahoning Valley, figures were taken from the charging books of several companies, and will be found in the table on page 541.

In regard to the character of the iron produced from these furnaces little need be said; from the character of the ore the iron is mad

generally to meet some special call, and may be of any quality desired, running from the purest Bessemer pig to iron made largely from mill cinder for use in rolling-mills.

An analysis of an iron made from Ohio ores in part is given, from Cherry Valley Iron Works, Leetonia:

Carbon	3.033
Silicon	3.850
Sulphur	0.016
Manganese	1.480
Phosphorus	0.794

The slag accompanying this iron was also analysed:

Silica	35.78
Alumina	11.69
Lime	49.65
Magnesia	0.82
Oxide manganese	0.72
Sulphur	1.55
Phosphorus	0.009

At Leetonia, in Columbiana county, are the works of the Grafton Iron Co. and Cherry Valley Iron Works. These latter make, from the New Lisbon kidney ore and Lake ore and mill cinder, with Connellsville coke, the American Scotch pig, already alluded to in a former part of the report. The works are provided with Pollock stoves, and with three blowing engines. The Grafton Iron Co. has two stacks, one just built; the hearth of their new furnace is built entirely closed, being merely provided with an opening through which the iron is to be tapped, the slag discharge being entirely independent of this opening. The furnace has six tuyeres, one over the tap-hole. The furnace is provided with two engines, one 84 in. by 4½ ft., and one 66 in. by 4 ft., running at 40 revolutions per minute; each furnace has two Player pipe-stoves; the blast is heated to 900 degrees, as shown by pyrometer; the works have a foundry in which the tuyeres and other castings are made.

The use of raw coal simply is perhaps best shown in the furnaces around Jackson, Ohio, and in the Hocking Valley. Several of these Jackson furnaces are outlined on plate 2, most of these using little or no mixture of coke. The table on page 541 gives figures from several of these furnaces, illustrating the average charge of ore, coal and limestone. Of the works at Jackson, the Tropic furnace is provided with

double horizontal blowing engines, 48 in. by 4 ft., and five 4-inch tuyeres; it has two Pollock stoves, with 32 pipes to a stove; these pipes are 8 in. by 11 in. in section, and 10½ to 11 ft. long; the blast pressure is about 4 lbs., and the temperature from 750 to 800; the average number of strokes of blast engine, 24. The Fulton furnace, of Jackson, is very similar in its general equipment, built, like all the raw coal furnaces in this vicinity, with iron shell or mantle, and lined as before described; has four 4-inch tuyeres, and pipe-stove with 48 pipes, 12 ft. long. The Milton Furnace and Coal Company, at Wellston, differs from the other furnaces in this district by being provided with three Whitwell stoves; the furnace is blown with five tuyeres, 4 to 5 in. in diameter. The new furnaces at Floodwood are also provided with fire-brick stoves of the Cowper-Siemens pattern, these being the only works using such stoves; the other furnaces in the Hocking Valley all using the simple Player pipe-stove. The number of men usually employed at these Jackson furnaces is from 25 to 30, sometimes fewer. In construction these furnaces are simpler, as a rule, thon those of the Mahoning Valley, the iron mantel and cast-iron columns being the invariable type. The other furnaces at Jackson and vicinity are the Star furnace, provided with horizontal blowing engines, 48 in. by 4½ ft.; Thomas pipe-stove of this district being practically the same as the Pollock stove of the Mahoning Valley; that is, having oval pipes divided by a central diaphragm; in this case the furnace has two stoves, with 32 pipes to each stove, uses a blast pressure of 4 lbs., and a temperature of possibly 800 degrees. The Huron furnace at Jackson has two horizontal blast engines, 48 in. by 5 ft, and six tuyeres, 3½ to 4 in., two Pollock and Davis stoves, 32 pipes to the stove, 8 by 11 in. in section, and 10 to 11 ft. long; the furnace is lined with fire-brick from Oak Hill, Ohio.

The Eliza furnace at Wellston has a vertical blast engine, 54 in. by 4 ft.; five tuyeres, 3½ by 4 in., lined with Webster fire-brick; has two stoves, with 32 pipes to the stove; these blast engines run about 25 revolutions per minute. These raw coal furnaces produce, as is seen by figures already given, excessive amounts of gas, which is utilized in heating the boilers and stoves, but is not all needed for this purpose; hence, at all these furnaces a large amount of superfluous gas may be seen burning to waste; that some of this might be economically used for roasting ore or other purposes would appear probable.

The gases produced from these coal furnaces are rich in combustible

matter, owing to the large amount of gas and volatile matter expelled from the coal, which loses thus 30 to 40 per cent. of its weight. It is well to observe, however, that while the gas is thus increased in heating power and value as a fuel, it is *not* largely increased in volume. To illustrate this, suppose a pound of average Brier Hill coal burned in the blast furnace, it would lose about 40 per cent. at the top of the furnace, representing tar, gas and water. The 60 per cent. coke left, which alone acts as fuel, will equal probably 56 per cent. carbon. This 0.56 pound of carbon will require 3.23 pounds, or about 44 cubic feet of air for its combustion at the tuyeres to carbonic oxide, and no matter how much carbon it may take up from ore and limestone, will represent at least 53 cubic feet of gas at the throat, assuming each volume of oxygen to make two volumes of carbonic oxide.

Three determinations made recently on samples of very dry burning coals, showed an average of about 3.7 cubic feet gas of to the pound; this is higher than the Brier Hill coal would yield, as the coals examined contained more volatile matter; even assuming the gas produced to be 4 cubic feet, the point is clear that the volume of the gas from a furnace using raw coal will not be more than *one-twelfth greater* than if the furnace was using the coke the coal used would produce; a fact which should settle, once for all, the question of different lines for coal furnaces, because of the large volume of gas!

The 53 cubic feet of gas considered above as furnished by the burning of the coke from 1 pound of coal, supposing it to do its full work in the furnace (supposed to be using 3.2 tons of coal to make 1 ton of iron) in the way of reduction, would have at the throat of the furnace about the following composition by weight:

Nitrogen	63.0
Carbonic oxide	27.7
Carbonic acid	9.3
	100.0

Its calorific power would be 665., or one hundred cubic feet of such gas would heat nearly 50. pounds of water from zero to boiling, assuming the mean specific gravity of the gases at 1.02. Adding now to the above gas the volatile matters from the coal (3.7 cubic feet having a specific gravity of about 0.6), the composition by weight would be nearly as follows:

Nitrogen	60.6
Carbonic oxide	26.6
Carbonic acid	8.8
Hydro-carbon gases	4.0
	100.0

And the calorific power (coal gas being taken at 24,000) 1,598, or 100 cubic feet would heat 115 pounds of water from zero to boiling.

The increase in heating power is probably even greater than this, as the gas carries over tar, etc, mechanically, which is far from all being deposited. The large amount of gas produced at the raw coal furnaces is due obviously to the large amounts of fuel used, and not to its nature.

The following table gives a number of facts relative to the furnace practice of the State; it is compiled from sources believed to be reliable; in most every case the charges are taken directly from the books.

As in the case of the charcoal furnaces, no attempt has been made to obtain figures from every furnace in the State—only a sufficient number to show the variety and general character of the work.

In the foregoing table, Nos. 1 to 4, inclusive, are furnaces in the Mahoning Valley district; Nos. 5 to 9, inclusive, furnaces in the Hanging Rock region, around Jackson and vicinity; No. 10, a furnace at Ironton, on the Ohio river, and Nos. 12 and 14, inclusive, are runs made in Hocking Valley furnaces.

The figures for iron produced, coal per ton of iron, limestone per ton of iron, etc., are uniformly stated in tons of 2,000 lbs. The practice, however, at all furnaces, is to calculate tons of iron as 2,268 lbs., tons of ore and cinder at 2,240, and tons of coal at either 2,240 or 2,000 lbs., according to the locality; in all cases, however, the reduction has been made from the local ton used to the standard of 2,000 lbs.

Calculating tons of 2,268 lbs. for iron, and tons of 2,000 lbs. for coal, the apparent consumption of fuel is much greater, and instead of 2.95 as in No. 13, would be 3.33.

One of the most interesting problems of the metallurgy of iron in Ohio is that relating to the smelting of native and other ores with raw coal. The practice has grown up without much help from scientific study, and without much investigation. The fact once ascertained, that raw coal would "do" to use in the furnace, little more was asked. Furnaces were built and iron was made without much care for what went into the furnace, so that iron came out at the bottom; consequently

COKE AND COAL FURNACES.

Number.	Stove used.	Blast cylinders—size.	Temperature of blast.	Length of run in days.	Charges and Product.							Tons iron per day.	Tons coal per ton iron.	Tons coke per ton iron.	Limestone per ton iron.	Total fuel, calculated as coke per ton iron.
					Coal.	Coke.	Lake or similar ores.	Native ore.	Mill cinder.	Limestone used.	Tons (2,000 lbs.) iron made.					
1	....	....	....	7	344,400 lbs.	861,000 lbs.	1,429,825 lbs.	....	....	465,428 lbs.	448.93	64.1	0.381	0.958	0.518	1.19
2	....	1. 30″x66″ 2. 35″x84″ 3. 36″x84″	....	1yr. 6½ mo.	31,417 tons.	27,553 tons.	20,881 tons.	12,678 tons.	13,887 tons.	25,340 tons.	31,302.94	56.0	1.138	0.998	0.918	1.68
3	Pollock..	1. 84″x4′ 2. 66″x4′ 3. 60″x4′ 4. 6′x6′	....	6	....	1,031,550 lbs.	286,692 lbs.	573,390 lbs.	286,693 lbs.	583,830 lbs.	288.04	48.0	....	1.790	1.013	1.79
4	Hamilton..	66″x4′ 6″	900°	7	154,800 lbs.	676,992 lbs.	856,560 lbs.	....	....	361,200 lbs.	257.42	37.0	0.300	1.302	0.70	1.48
5	Pipe	48″x4′	750°	7	446 tons.	....	56 tons.	158 tons.	58 tons.	154 tons.	158.76	22.6	3.18	....	1.10	1.91
6	Whitwell..	72″x4′ 6″	11,000°	31	49,473 bus.	....	....	1,074 "	274 "	782 "	743.70	24.0	2.66	....	1.05	1.60
7	Davis........	54″x4′	750°	7	8,275 "	....	....	201.51 "	(?)	114 "	117.80	17.0	2.81	....	1.09	1.69
8	Thomas ...	48″x4′ 6″	....	118½	164,640 "	....	937.1 tons.	2,873.9 "	750 "	2,198.8 "	2,123.98	18.0	3.10	....	1.03	1.86
9	Pollock.....	48″x4′	750°	21	1,024 tons.	....	....	434 "	243 "	427 "	357.80	17.0	3.17	....	1.32	1.90
10	Whitwell..	72″x4′	....	56	1,649,946 lbs.	4,538,291 lbs.	....	7,035,200 lbs.	....	4,828,200 lbs.	1,764.84	31.0	0.467	1.29	1.36	1.57
11	Pipe	54″x48″	900°	6 d. 17 hrs.	1,193,400 "	....	197,600 lbs.	544,270 "	131,010 lbs.	565,610 "	215.50	32.1	2.77	....	1.32	1.66
12	"	54″x48″	880°	7	1,360,000 "	....	145,280 "	625,120 "	204,140 "	641,660 "	230.00	32.9	2.95	....	1.39	1.77
13	"	....	....	6 d. 9 hrs.	1,224,000 "	....	246,480 "	460,440 "	210,840 "	638,040 "	236.00	36.9	2.60	....	1.35	1.56

during the first few years of the development of the Hocking Valley district, some curious records were made as to fuel used and quality of iron produced.

There are several points in regard to the action of this fuel of so great interest as well as peculiarity, that it is proposed to devote some space to their consideration.

One of the first points is the large amount of fuel used. Turning to the table of furnace charges, it appears that from 2.6 to 3.18 times the weight of iron made is needed in fuel, and the lower figure is only reached when exceptionally rich charges are used (largely lake ore and cinder). Again, exceptionally large burdens of limestone are carried.

As to the iron made, it is often, if not usually, high in silicon, frequently being very silvery. This composition will be well shown by the following set of analyses, made at the Ohio State University by the writer:

	1	2	3	4	5	6
Carbon (graphite)	3.55	2.89	2.62	2.66	3.25	3.13
Carbon combined	undet.	trace.	0.40	0.26		
Silicon	3.86	6.09	3 73	3.70	3.17	4.31
Sulphur	trace.	undet.	0.08	0.21	trace.	undet.
Phosphorus	0.50	undet.	0.53	0.60	0.656	undet.

1. Foundry iron, Straitsville.
2. "Silver gray" iron, same locality.
3. No. 1 iron, Jackson.
4. Mill iron, Star furnace, Jackson.
5. Gray foundry, Hocking Valley.
6. Straitsville.

It is but proper to say that these are mostly of samples taken two to three years ago; the present practice is better. Still much silvery iron is made now, and constitutes one of the valley brands—it is valuable as a mixture, but still is not the normal or best product of a furnace.

The peculiarity of the working must lie in the mixtures; there is great diversity of furnace lines, but nothing so different from the coke furnaces as to give them a special character.

In order to examine this working, the slag formation and fuel consumption, also the probable heat distribution in the furnace, will be considered and compared with that of other furnaces.

First, however, it will be well to make a few preliminary statements in regard to slags. The characters of the slag that concern the metallurgist are its fusibility and its fluidity. Combinations of silica, lime and alumina are fusible between very wide limits in composition, but they differ greatly, not only in the temperature at which they fuse, but in the character of the fusion, some melting immediately to a liquid which flows freely, some becoming gradually soft, and passing through all grades from hard to liquid. These two methods of melting may be illustrated by respectively the melting of tar and the melting of lead, one passing slowly from the solid to the liquid state, the other almost instantly. As is well known, the slags of charcoal furnaces have the viscid character; the composition accompanying this character is shown by the analysis made of slags from charcoal furnaces in the Hanging Rock region, published in this report. It will be seen that the percentage of silica is high. In general, it may be stated, experiments have shown that slags in which the percentage of silica was high, had this character.

Slags from coke and coal furnaces have compositions illustrated by the following analysis:

	1.	2.	3.	4.
Silica	38.10	35.78	30.66	36.41
Alumina	16.00	11.69	13.75	12.88
Lime	39.09	49.65	50.97	47.43
Magnesia	4.41	0.82	2.66	1.15
Protoxide of iron	.30	undet.	undet.	undet.
Protoxide of manganese	.50	.92	.60	.72
Sulphur	undet.	1.55	2.21	1.68

1. Cinder, Hocking Valley.

Such slags melt differently, becoming suddenly liquid and solidifying with equal rapidity, so that in running from the furnace, crusts of

solid slag form, while the interior portion is perfectly liquid. While, however, the more basic silicates, that is, those containing less silica and more lime, become more liquid, when melted they fuse with greater difficulty. Of the other elements besides silica in these slags, lime is the principal. A mixture of silica and lime alone is practically infusible; alumina also forms an infusible mixture with silica; a mixture of these three materials, however, forms the fusible slag of the blast furnaces. Many experiments made on these mixtures show that the most fusible compounds are those in which the silica forms from 30 to 50 parts of the whole, and the alumina forms about $\frac{1}{2}$ to $\frac{1}{4}$ part of the lime. If the alumina becomes very small in proportion to the lime the slag becomes much more infusible. Magnesia acts as lime, but when mixed with lime in the slag tends to increase the fusibility of the mixture over what it would be if pure lime alone were used. This is true, provided the percentage of magnesia be not too great; hence, in many cases where alumina is so deficient in a charge as to render the obtaining of a proper proportion impossible, the use of magnesian limestones, containing 9 to 10 per cent. of carbonate of magnesia, is sometimes found advantageous. The sources of the slag forming constituents in a blast furnace are the ores, the limestone and the fuel; the ore can be considered as a known and nearly constant quantity in the present discussion; the limestone will vary from furnace to furnace, but for all practical purposes may be considered as consisting of a mixture of pure carbonates of lime and magnesia with silicious matter (the material left untouched when the limestone is dissolved in acids). The composition of this is important. A series of analyses made in the laboratory of the State University, in which the silicious matter was determined, and also its content in silica, shows that on the average this silicious matter contains $\frac{2}{3}$ of silica and $\frac{1}{3}$ alumina, or closely approximates clay in composition; the addition of lime to this would but imperfectly flux it; still it is customary to regard it as entirely fluxed by the lime of the limestone, and to deduct from the total carbonates of lime and magnesia present, twice the amount of this silicious matter as used up by it, leaving the rest available. This is a sufficiently near approximation to the truth to serve as a means of comparing different limestones for furnace use. The third of the series of slag making materials is the ash of the fuel; this may be regarded as having a mean composition, as follows:

Silica	55
Alumina	35
Oxide of iron	5 to 10
Lime	0 to 5

This is based on a number of analyses made of the ashes of the Hocking Valley coals, both by Prof. Wormley and the present chemist of the Survey. The composition is quite similar to that of the silicious matter of the limestone, consisting essentially of a mixture of alumina and silica in the proportion of 3 to 5. In regard to the amount of this ash introduced into the furnace in smelting with raw coal it is about as follows: Assuming the consumption to be 3 tons of coal to the ton of iron, and taking the average of a number of analyses of the coal already given, we find the percentage of ash to be 4.5; three times this represents the amount on the iron made, and taking the consumption of ore per ton of iron as 2.1 tons, the coal ash amounts to 6.4 per cent. of the ore used. The importance of this coal ash, however, as a slag forming element, is greater than the mere amount of silicious matter that it introduces, owing to its containing so large a percentage of alumina, the effect being to increase very decidedly the amount of this element in the slag.

Assuming the foregoing statements, two points of interest appear; first, what kind of slag is produced; and second, what role do the coal ashes play in its formation.

Most of the furnaces at present use but a portion of native ore; however, the following record, where mill cinder is the only addition, will be taken as a basis for calculation. The figures represent three weeks' run of a raw coal furnace:

Charges.	Tons.
Coal	1024
Native ore	434
Mill cinder	243
Limestone	427
Iron produced	323
Coal used to one ton of iron	3.17
Ore used to one ton of iron	1.35
Mill cinder for one ton of iron	.75

The composition of the Jackson shaft coal (this being the coal used) is shown by the following analysis:

Volatile material and water	41.27
Fixed carbon	55.43
Ash	3.30

This ash is lower than the average, and in the calculation the ash will be assumed at $4\frac{1}{2}$ per cent.

The composition of mill cinder will be shown by the following analysis:

	1.	2.
Silica	27.34	22.76
Alumina	2.18	3.10
Oxide of manganese	....	2.38
Lime	0.75	2.40
Magnesia	.20	0.34
Phosphorus	.32	1.80
Iron	47.	50.6
Sulphur	0.65	0.19

1. Flue cinder.
2. Tap cinder.

A number of iron determinations in various cinders show that these are lower than usual; hence, for the present calculation, an average of silica 23 per cent., alumina $2\frac{1}{2}$ per cent., and iron 51 per cent. will be assumed.

It will be necessary to calculate the composition of the ore and its richness, from the yield; special analyses before given will serve to show the ratio between the elements which make up the gangue of the ore, but their total amount is best obtained by knowing the iron yield.

Analysis of the iron shows it to be as follows (the sample is from a furnace smelting the same mixture, and will not vary appreciably):

Graphite	2.61
Combined carbon	.30
Silicon	3.70
Phosphorus	.76
	7.37
Metallic iron	92.50

The yield of the ore and cinder was 323 tons of pig-iron; this contains 298.8 tons of iron; of this the cinder gave 123.9 tons, leaving 174.9 tons derived from the 434 tons of ore; this corresponds to 40.3 per cent. of iron. The small amount of iron in the coal ash and limestone has been neglected, as it is only about equivalent to the small amount taken up by the slag.

As the ore is roasted the iron must be calculated as sesquioxide, of which it will furnish 57.5 per cent.; the difference between this and 100 shows the amount of earthy material in the ore; it is 42.5 per cent. This shows the ore to be on the average poorer than is found by analyses of single specimens; such an analysis of average roasted ore showed:

Sesquioxide of iron	63.78
Silica	22.15
Alumina	9.31
Lime and magnesia	1.64

This relation between the silica, alumina and lime of the ore may be safely assumed.

Stating in tabular form the material which makes up the slag, we have as follows:

	Tons.
Furnished by ore	184.4
" cinder	72.9
" coal ash (4.5 %)	48.1
" limestone	248.5
Total	553.9

From this should be deducted the silica and phosphorus, corresponding to that in the pig-iron, which amount to nearly 10 per cent. of the iron (the silicon received as silica and the phosphorus as acid.) The slag left after making this deduction is 521.6 tons, or 1.6 tons for each ton of pig-iron made.

The distribution of the lime, alumina and silica would be as follows, taking the analyses given as correct:

	Silica.	Alumina.	Lime.
Ore	118.8 tons.	55.2 tons.	10.0 tons.
Cinder	55.8 "	6.1 "	2.4 "
Coal ash	26.4 "	16.8 "	2.0 "
Limestone	12.8 "	8.5 "	227.2 "
Total	213.8 tons.	86.6 tons.	241.6 tons.

From this silica it is necessary to deduct what goes into the pig-iron, or 25.8 tons, leaving 188 tons silica for slag. The comparative percentage calculated from this would be:

	1	2
Silica	36.4	38.1
Alumina	16.2	16.0
Lime (magnesia)	47.4	43.5
Oxide iron, manganese, etc.	....	2.0

No. 2 is an analysis of a slag from a coal furnace; it serves to show that the character of the slag found corresponds to practice. Examining these results, it is evident that the slag is very fine and produced in very large quantity. Furthermore, the ash of the coal included above does not become a part of the slag until the fuel is burned at the tuyeres. Now, if these coal ashes are omitted from the above slag calculation, the resultant slag would be decidedly ($\frac{1}{5}$) lower in alumina and also in silica (about $\frac{1}{9}$).

Now, while these slags form a very liquid compound, they require a very *high* temperature for their formation and fusion, and hence it would appear, require a very hot hearth for their melting. The silica in the coal ash at this high temperature is almost immediately reduced, and goes to the iron. The extremly basic slags are necessary to pre-

vent this as far as possible, but evidently they only partially correct the evil.

Hence, one reason for this silvery character of the iron would appear to be the high temperature necessitated by the large amounts of ore and slag in the hearth; in other words, the mixture must be such as to give a slag so basic that it can absorb the coal ashes without passing beyond a proto-silicate. This condition is only possible when the volume of slag is large and the hearth very hot.

The second point from which the smelting was to be considered, was the fuel consumption and heat distribution.

The fuel used was stated at about 3 times the iron made. Assuming a yield of 60 per cent. in coke, this gives 1.8 tons of coke for 1 ton of iron, or, in the case above discussed, 1.9 tons of coke. If an estimate of the heat required in the furnace be made, as in the case of the charcoal furnaces before discussed, it appears that this amount of fuel is very excessive.

Bell estimates the heat required to make iron from Cleveland ore at 4,670 units per unit of iron (Chemical Phenomena of Iron Smelting, p. 151). With the ores of this State, and raw coal, this requirement would be greater, as the slag would be a little, and the amount of gases considerably increased. The amount of gas produced from the coal furnaces per ton of iron made is from 9 to 10 tons, as against 6.9 to 7.5 tons in Bell's coke furnaces. This would mean an increase of heat requirement of perhaps altogether 200 units, making the total perhaps 4,870 units. Now, against this requirement, the fuel consumption shows an enormous heat production; to tell just how much, the analysis of the furnace gas would be necessary. Now this excess means two things— first, a great waste of fuel, due to bad working, letting the iron reduction take place in such a way that carbon instead of carbonic oxide reduces iron. This can be corrected by better lines for furnaces, greater height and more capacity, but there is probably another source of heat consumption not allowed for by Bell, and unavoidable with the fuel. The heat required to coke the coal in the top of the furnace is probably larger than usually supposed. If 4,870 heat units be assumed as required to do this work of the furnace, an approximate calculation of the heat production in the furnace under discussion may be made as follows: Of the 1.76 tons carbon, 1.4 tons are assumed to burn at the tuyeres, .36 tons being enough to reduce all the carbonic acid of the

1.32 tons of limestone used, and leaves 0.18 tons to reduce carbonic acid from the ore reduction, and .03 tons for the iron. This .18 tons of carbon will reduce more than half the carbonic acid produced in ore reduction, but one-half at least will be assumed to escape and furnish heat. The heat production will then be:

1.4 tons carbon burned at tuyeres to carbonic oxide	3,360
One-half the heat produced by ore reduction	840
Heat of blast, 8 tons at 550° centigrade (specific heat .24)	1,056
Total heat produced	5,256

This is based on the most unfavorable, possible working. It is probable that the analysis of the gases from any raw coal furnace would show more carbonic acid than has been allowed for, and hence, a greater excess of heat produced; this excess would certainly appear to be caused by the absorption of heat on coking. If this is true, the effect is not only to cause the use of more fuel, but by withdrawing heat from the top of the furnace, it tends to make the heat production in the hearth out of proportion to that in the stack, and hence to make a hot crucible and silvery iron.

It would hence appear, that the peculiar results obtained in raw coal smelting are at least partly explained from the character of the slags, and the fuel causing both a hot hearth and cold shaft, on account of bad heat distribution and too much ash.

These considerations would point to the desirability of very hot blast for the raw coal furnaces, so as to lighten the amount of fuel burned at the tuyeres. Full figures relative to this are not at present attainable, but those given in the table certainly show a great advantage in very hot blast.

There are several other questions as to smelting which are important, and upon which notes, obtained in the laboratory of the Survey, may throw light.

The assumption has been made that all the phosphorus in the ore and charge went into the iron. To make sure of this, several slags were examined for phosphorus.

The highest percentage in a series of 6 analyses was .009, or less than .01 of one per cent.; this slag was from a furnace producing a pig-iron with 0.70 per cent. phosphorus, and giving a very basic slag.

The ashes of coals contain in all cases some phosphorus; samples

have yielded Dr. Wormley as high as 2 per cent. of the ash, though generally much less.

It certainly would pay to have the ashes examined for phosphorus before using a new coal, especially where the lake ores are used to carry mill cinder, as is now so generally done in the State. The cinder being very cheap, the more that can be used the better, provided the quality of the iron does not suffer.

Another source of phosphorus is the limestone. All limestone contains traces of this element. Analyses in the Ohio State University laboratory have shown the following percentages in limestones used for furnace purposes:

	1	2	3	4
Phosphorus..........	.067	.035	.052	.14

1 and 2. Owen's Quarry, used by Winona furnace.

3 and 4. Shawnee limestone.

Occasionally the per cent. becomes very large. A layer in the Columbus quarries contains in certain specimens as high as 8 or 10 per cent. of phosphoric acid, and this material occasionally gets into cars loaded for the Hocking Valley furnaces.

The extensive use of mill cinder has been discussed somewhat. The peculiarity of this material is its highly silicous character and its fusibility. Its variability in percentage of phosphorus and of iron has been shown, but besides these drawbacks, without great care in smelting, it is liable to reach the hearth of the furnace unreduced, when it acts as a corrosive slag, and also makes masses of wrought iron collect there, the oxide of iron in the slag acting as a decarbonizer on the iron in the hearth.

A furnace at Steubenville was during 1880 running almost exclusively on mill cinder; the campaign was successful, a fair mill iron being produced. When the furnace was blown out, a mass of wrought-iron or salamander at least 6 feet in diameter was removed from the hearth of the furnace.

The method of treating these salamanders was curious; they were drilled into by a steel drill to a depth of two-thirds or more the di-

ameter, and then blasted with nitro-glycerine or dynamite; this broke the salamanders into manageable pieces. Gunpowder failed to effect the rupture; the tube simply shot off like a gun, leaving the mass unbroken; the high explosives answered the purpose, however.

These masses when melted with coke in a high cupola furnace gave a fair iron, the carbon being added by the coke.

This statement of the method of working was made by the furnace company. The blasting was in operation at the furnace. The masses were sold to a furnace near Youngstown for melting.

The following analysis of a salamander of another sort is added here as being of interest; it is a series of fused mass of ash and slag, and is a good illustration of what coal ashes will do in the hearth:

Slag Salamander.

Silica	49.53
Alumina	22.18
Oxide of iron	9.16
Lime	15.23
Magnesia	2.12
Oxide of manganese	2.00

Conclusion.

This review of iron smelting in Ohio shows that there is much to be done in the direction of improving the results obtained from raw coal smelting, and indicates the kind of experiments which must be made to effect this object.

Careful analyses of all products and materials of the blast-furnaces, including, and perhaps most important of all, the analysis of the gas from the throat of the furnace, are necessary to intelligently compare the results of working between different furnaces and different sections.

The mere knowledge of the fact that one furnace is making iron with so much coal, while another requires perhaps 30 per cent. more, is no indication that the first is doing better work than the second. The objects to be obtained in smelting are the utilization of the fuel applied, so that as little as is consistent with the character of the materials to be smelted may be used. The objects that lead to the accomplishment of this result are the arranging of the furnace so as to entirely effect

the reduction of the iron ore by the carbonic oxide of the gas, and the preventing of the use of solid carbon in the upper part of the furnace, instead of at the tuyeres; but as the sensible heat of the furnace is almost entirely derived from the combustion of carbon to carbonic oxide at the tuyeres, it is obvious that what causes in all cases the greatest use of fuel is the necessity of a large heat production there from having in the hearth an excessive amount of material to be heated; in other words, every addition to the amount of slag produced in the furnace calls for a large addition to the amount of fuel; carbon burned to carbonic acid furnishes 8,000 heat units; whereas, burned to carbonic oxide, as at the tuyeres, it merely furnishes 2,400 heat units, or less than one-third the former amount.

The increase of the amount of slag from one to two tons to the ton of iron would require on that account alone the increase of the fuel from 1.2 to 1.4 tons to the ton of iron, for this extra ton of slag withdraws 500 to 600 units of heat. The fuel necessary to furnish this heat at the tuyeres would be 600-2,400, or $\frac{1}{4}$ ton; if this be calculated as raw coal it means about half a ton. The real increase is even greater than this, as the added fuel means increased blast and gas also.

It seems as though this fact would largely determine the economy of every endeavor to enrich the mean composition of the ore charges.

That this theoretical deduction is not without its practical value, is shown by the fact that most of the large furnaces are giving up the use of lean ores where rich mixtures even at higher prices can be obtained. When a furnace, by using Lake ore and coke, can make a ton of iron with but little more than a ton of coke, it becomes a simple matter of calculation as to whether it will pay to replace the rich ore by a low grade cheap one. The increased amount of coal is not the only evil, but as the capacity of a furnace is not really measured in the iron it makes but in the fuel it burns; the increase in fuel used is really a diminution in the production of the furnace, and the consequent increase in cost of the iron by the proportionate amount of the total fixed expense of the works. It is the want of consideration of these matters which has led to the erection and subsequent abandonment of more than one large and expensive furnace after treating poor ores.

It is the same fact that makes all methods by which the mean richness of the ore can be increased so valuable as an adjunct to iron smelt-

ing, making them economical even more than can be directly calculated from the cost of the process. To what extent the use of the rich Lake Superior and Missouri ores is going to replace the consumption of the leaner Ohio ores it is hard to foretell, for the question will be settled by rates of transportation and facilities for production.

CHAPTER VII.

THE MANUFACTURE OF COKE.

By Henry Newton, E.M.*

Coke is the combustible residue remaining after the volatile parts of a bituminous coal have been expelled by heat. The objects aimed at in its manufacture are, 1st, to obtain a fuel of a higher calorific power and greater density, and 2nd, to obtain from the cementing or coking coals a fuel which will not agglomerate in the furnace. A small amount of sulphur is also at the same time expelled.

All varieties of bituminous coal may be made to produce a coke, but the character of the coke will vary very greatly with the kind of coal. Usually it is customary to coke only those coals in which the cementing or coking character is well marked—the coking coals—and which cannot be used raw in the furnace, because of their cementing together and clogging up the furnace. The non-cementing or open burning coals, though they will produce a coke, which, however, is very light, porous and fragile, because of their free burning character, are used in the blast furnace in the raw state.

The early iron industry in all countries was dependent on the use of charcoal, and the precise time of the first manufacture and use of

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* Mr. Henry Newton, E.M., whose untimely death in 1877 was deplored by all who knew him, was employed for parts of several years by Dr Newberry in the collection and preparation of materials for the volume on Economic Geology, which the Legislature had ordered. The chapters which Mr. Newton had prepared for publication pertained exclusively to the various subjects connected with the manufacture of iron. Professor Lord has used some of this material in the preceding chapter, with due acknowledgment, but it is deemed fitting that at least one chapter of the present volume be given in Mr. Newton's own words. For this purpose, the Chapter on Coke seems to be the best adapted, and it is accordingly introduced at this point. A few analyses have been added by Professor Lord, but the text is in all essential respects as it was left by the author.

The chapter might have been made somewhat fresher by the introduction of the investigations and experiments of the last 8 or 10 years, but as it is, its statements will be found clear, compact and reliable, fitly representing in these particulars the mind and work of the author.

The coke interest of Ohio is not a large nor a growing interest, as will be seen from the chapters of the present volume that treat of our coal fields. The production of inferior grades of coke from slack and refuse coal is extending somewhat, but Leetonia is the only point in Ohio in which iron-making is now carried on by the exclusive use of native coke. E. O.

coke is a question upon which we have no precise information. Dr. Percy records that Jeremiah Buck obtained a patent in England in 1651, for the manufacture of iron with *coal not carbonized,* and he infers therefore that coke must have been previously known. Plot published in 1686 a history of Staffordshire, and there speaks of the carbonization of coal in heaps, as is done in the making of charcoal, and the production of "coak," which was used for drying malt. Swedenborg visiting England in 1734, mentions that coke was used in some districts for the production of iron.

M. de Gensaune, in his "Traite' de la Fonte, etc.," published in Paris in 1770, described and illustrated ovens erected at Sultzbach by the Prince of Nassau, for the production of coke, and in 1774, M. Jars gave illustrations of the furnaces used at New Castle for reducing coal to "coaks."

The use of raw coal, however, in the production of iron in the blast-furnace was already well known. Lord Dudley, commonly known as Dud Dudley, in 1619 had experimented with it, but was unsuccessful, and it was left nearly a century later, in 1713, to Abraham Darby, who succeeded in the attempt at the Coalbrookdale Iron Works.

Owing to the increasing scarcity of charcoal about the year 1750, the production of iron in England fell considerably, and there was much solicitude expressed at the large amount of iron then imported from Sweden, and from about the year 1775 is to be dated the more general manufacture and use of coke in the production of iron in England. In 1783 the authorities state that the use of coke had become general in England.

In France the application of coke dates from 1769, when it was used for smelting copper ores, and in the foundry at Villefort, but in Belgium, though begun in 1811, its use was not well established until 1823 in the Liege coal basin.

In the United States the iron manufacture in the earlier periods of our history was exclusively carried on by the use of charcoal, but with the increased scarcity of wood it has been driven in most cases to the margins of the thickly settled regions, and from this cause and the increased demand for iron, the place of charcoal is now being supplied by mineral fuel, anthracite, bituminous coal and coke, and in the larger iron regions these are used exclusively.

The application of anthracite in the manufacture of iron in the

blast furnace was patented December 19, 1833, by Dr. F. W. Geisenheimer, of Pennsylvania, and experiments were made at the Valley Furnace near Pottsville, which, however, were unsuccessful. Other attempts followed, and the first authentic account of success is that of a small furnace built near Mauch Chunk, by Baughman, Guiteau & Co., in 1838. In 1839 the Lehigh Crane Iron Co. was established, and the first furnace was built at Hokendaqua, by Mr. David Thomas, who had come out from South Wales, where Mr. Geo. Crane had in 1837 succeeded in using the Welsh anthracites. Anthracite coal was used in this furnace, and from this time its consumption in the manufacture of iron has steadily increased, till in 1872, of the total pig-iron made in the country, 52 per cent. were produced in Eastern Pennsylvania, New Jersey and New York with anthracite.

Concerning the first use of raw bituminous coal and coke, we have not such accurate information, but in 1845, coke was made at the Clay Furnace in the Shenango Valley, Pa., from the block, or Brier Hill coal, and in the same year it was abandoned for the use of raw coal. This is unquestionably the first instance of the use of raw coal in the United States in the iron manufacture, and from that time its use has increased in many regions where the open burning coals are found, as in Shenango Valley, Pa., Mahoning Valley, O., Central and Southern Ohio, Indiana, etc.

Coke varies greatly in physical character, depending on the coal employed and the method of its manufacture. It is always more or less porous, but it may vary from a very light and cellular mass to one comparatively dense and hard. It may be so friable as to present but little resistance to crushing, as the coke made from many dry coals and that produced in the manufacture of illuminating gas, or it may be very hard and resistant, requiring considerable pressure to crush it. The following table gives the results of experiments made upon several cokes to determine their resistance to crushing, and gives the pounds per cubic inch that were necessary to crush the specimen:

	Pounds per square inch.	No. of experiments.
Durham coke (England)	1,090	2
Connellsville coke (Penn.)	1,083	3

In color, coke varies from a dull black to light gray, with a brilliant silvery lustre; when hard and dense it is quite sonorous.

With a difference in their density and purity, cokes also differ in their combustibility, and while for metallurgical purposes a dense coke is preferable, this hardness increases to an undesirable extent its incombustibility, and the amount of fuel required, as is observed by several European authorities.

Coke made in the manufacture of gas is usually, from its friability and impurities, unfitted for metallurgical purposes, and to be suitable for such use, coke should be sufficiently hard to resist the pressure of the material, ore, etc., and as free as possible from impurities, which reduce the heating power and contaminate the material with which it may be in contact.

Composition of coke. Cokes are composed of carbon and ash, besides retaining a small proportion of volatile matter, water, hydrogen, nitrogen, etc. Usually it will not retain more than 1 per cent. of water when exposed to a damp atmosphere, or even when it has been quenched by water, when freshly made. When perfectly dry, and immersed in water for 24 hours, it may absorb as high as 51 per cent. of its weight of water, which is the greatest quantity absorbed by 12 trials made by Dr. Percy. This, however, was rapidly evaporated on exposure to the air. When well made, the total proportion of volatile matter in coke rarely exceeds 2 or 2½ per cent.

The ash in cokes varies very greatly, and depends on that of the coal employed, and will be from 25 to 40 per cent. greater than the coal from which it was made. Though many cokes used contain 14 per cent. or more of ash, a really good coke should not have more than 8 per cent., and when the coal will produce a coke containing a greater proportion, it should be submitted to a preliminary operation of washing. In France, as already observed, the coals are very impure, containing 20 per cent. of ash, and good cokes with 8 to 10 per cent. of ash are only obtained by the most careful washing of the coal. The same remarks apply to the Belgian cokes, though the coals are somewhat purer than the French. The English cokes are usually quite pure, and the composition of the typical coke, the Durham, is given in the following table of analyses. In the United States, though there are many bituminous coals, especially in the Allegheny basin, which will produce very pure cokes, many of our coals, particularly those of the Mississippi basins, will require washing before they will produce a good metallurgical coke. Already the importance of purity in the coke used

in the blast-furnace is becoming appreciated, and a preliminary washing of the coal is now conducted in many places in our iron regions.

In the following table analyses are given of many of our American cokes used in iron manufacture, and several from European countries, for comparison with them:

	1.	2.	3.	4.	5.	6.
Water	0.40	....	....	....	0.49	0.657
Volatile matter	1.30	....	....	....	....	1.404
Carbon	91.28	95.50	89.30	89.28	87.456	84.289
Sulphur	1.97	1.20	2.66	1.06	0.693	0.711
Ash	7.38	3.30	8.04	9.66	11.332	13.650
	100.	100.	100.	100.	110.	100.

1. Mingo Junction, Ohio.
2. Washingtonville, Ohio.
3. Leetonia, Ohio.
4. Broad Top, Pennsylvania (washed).
5. Connellsville.
6. Connellsville.

	7.	8.	9.	10.	11.
Water	0.11	....	....	0.2	3.62
Volatile matter	0.35	....	....	1.5	16.92
Carbon	92.18	88.08	88.77	90.1	69.97
Sulphur	0.618	1.03	1.13	2.51	....
Ash	6.68	10.88	10.10	8 2	9 49
	....	99.99	100.	....	....

7. Fire Creek, West Virginia. Britton.
8. Average of three analyses, Connellsville coke, Penn. Geol. Report.
9. Average of six analyses, Connellsville coke, from washed coals, Penn. Rept.
10. Coke from Bayley's Run coal, Hocking Valley (Average). Lord.
11. Coke made in piles, Moxahala Furnace, Ohio. Lord.

	12.	13.	14.
Carbon	82.31	93.15	91.59
Hydrogen	0.55	0.72	0.47
Nitrogen	....	1.28	} 2.05
Oxygen	....	0.90	
Sulphur	2.24	....	......
Ash	14.90	3.95	5.89
	100.	100.	100.

12. Big Vein, Salineville. Wormley.
13. Durham coke (England).
14. Coke from Mons basin (France).

The composition of the ash of coke will, of course, be essentially the same as that of the coals from which they are made, and such analyses have already been given. The sulphur, however, is somewhat reduced in amount. It may be generally said that $\frac{1}{2}$ of the sulphur in a coal is expelled in the process of coking, or that the coke will retain about three-quarters of the sulphur in the coal. When, however, the sulphur exists in some other combination than the sulphide of iron, as in the probable organic sulphur compounds alluded to, a somewhat larger proportion is expelled in coking.

The manufacture of coke may be conducted by three methods:

1. Coking in simple heaps or piles, as in the carbonization of wood.
2. Coking between walls or in kilns.
3. Coking in closed ovens or furnaces of various forms.

1. *Coking in heaps.* The manufacture of coke in heaps or piles is the oldest method for its production, and though still used in some districts in England and in this country, it is fast giving way to the more perfect and economical process of coking in ovens.

The heaps are sometimes circular in form, but more commonly rectangular, having a length of from 50 to 200 feet. The operation of coking in piles is in many respects similar to charcoal making, and though simple and requiring little outlay, it is by no means economical, as there is a large loss from the unavoidable burning to waste of a part of the coal. The yield of coke made in this manner is 20 to 30 per cent. less than when the same coal is coked in ovens, and the coke is not so dense, and more care is required in the conduct of the operation. The coke heaps are made in the same area, and usually at the furnace a portion of the yard being set apart for that purpose, which soon becomes covered with the fine coke dust or breeze, which is used for covering the surface of the piles.

Circular heaps are not employed in this country, but they are used in some parts of England. At the center of the base, which is from 25 to 30 feet in diameter, a chimney is loosely built of brick, generally circular in section. A number of holes are left in the chimney by omitting here and there a brick. The coal is piled around this chimney, the

larger pieces being placed near the center, and a mound of this kind, 30 feet in diameter, and 5 feet high, will contain about 20 tons of coal. The exterior of the pile is covered with a bed of fine coke or breeze 3 or 4 inches in thickness, which is packed down tightly to exclude the air, excepting a height of about 1 foot around the base, which is left uncovered. The pile is lighted by dropping some burning coals down the chimney, through the openings of which the coal is lighted, beginning at the base, and being propagated in all directions toward the cover. At the base of the pile where there is no cover, a small amount of air is admitted by which the combustion is sustained in the pile. A thick smoke soon rises from the exterior, and the flame, which is often very brilliant, escapes from the chimney. In 4 or 5 days the fire will reach the cover, which then becomes red-hot, and the carbonization is then complete. The chimney is now closed by an iron plate, and the base of the pile, which has been left uncovered, is tightly sealed by moistened coke dust, as well as any other portion of the cover that may be broken. The management of the pile requires no little skill, especially if the weather be bad or the wind blows, to prevent an unequal burning of the mound and a waste of the coal. At the end of 2 or 3 days the pile will have become cool enough to permit the removal of the coke, which may then be quenched with water and drawn. The yield of coke from the Staffordshire coals, which are dry, is between 50 and 60 per cent.; and while the product is not uniforn, only the large pieces of coal can be employed in the construction of the pile.

The circular piles are sometimes made without any covering, and being lighted at the centre, where the fire reaches any portion of the exterior, as is shown by a coating of ashes, it is quenched by a covering of coke dust, and when the whole pile is so covered it is left to cool. The piles are also made with channels at the base, which radiate from the central chimney to the circumference. They are made of the larger pieces of coal, and permit a regular admission of air to the pile, which otherwise is tightly covered by fine coal or coke dust.

Rectangular piles or pits are used to some extent in England, and though formerly employed in many of the iron works of the United States, as at Johnstown, Hollidaysburgh, etc., they have in most instances given place to the use of ovens.

There is a form of rectangular pile used at the Bowery Furnace,

Maryland, the facts concerning the working of which have been kindly furnished by my friend, Mr. E. F. Wendt, E.M., the Superintendent. The coal used is the semi-bituminous coal of the Cumberland coal basin, containing about 75 per cent. of fixed carbon. The piles are rectangular in plan, 42 by 12 ft., and conical in cross-section formed like the ridge of a roof, 5 feet in height. A flue is first built with the large pieces of coal, "lumps" or "tops," on the base of the proposed pile along the axes of its greater dimension, and smaller pieces, about the size of a man's head, are carefully laid against them over the whole area of the pit. This is called the "bottom," and requires three layers to complete it. The pile is made upon this bottom by shoveling the coal upon it with pronged shovels, the prongs of which are $1\frac{3}{4}$ inches apart, and the whole is then finished by a covering of the fine coal, which is well moistened and beaten down, excepting a small space around the base, which is left uncovered. A pile of this shape and dimensions will contain 40 tons of coal. Fire is given to the pit at both ends of the central flue, and owing to the circulation through the flue and between the larger lumps of coal forming the bottom, the entire base is soon a glowing mass. The fire rises thence toward the top, and is followed by covering the lower portion of the pile with coke dust and ashes. In ordinary weather about 9 inches are left between the fire and the edge of the covering, but in wet weather this space is increased, and a greater draught is therefore given. When the fire has been driven to the top, which requires 8 or 9 days, and the pit is covered, it is left one or two days to cool. Holes are then punctured in the pile by a crow-bar, and water is run into the interior at a number of places in order to hasten its cooling and permit the removal of the cover, and breaking up of the pit. If, however, the pit is allowed to cool by itself or is smothered, it will require 5 days before the coke can be removed. As the coke is all removed by pronged shovels, a considerable quantity of fine coke or breeze is left in the yard, which is used for covering subsequent pits.

The character and yield of coke will vary with the rapidity of the operation and the care with which it is done, but to obtain the best results, fully 2 weeks are required. The yield of the Cumberland coal in these pits is $48\frac{1}{2}$ per cent., or a 40-ton pit of coal will yield about 20 tons of coke.

For the production of 50 tons of coke per day there will be re-

quired 54 piles of the dimensions given, occupying a good 300x250 ft., and the labor of 23 men.

At Hollidaysburgh, Pa., coke was formerly made in heaps about 12 feet wide at the base, and 2 ft. 8 in. in height, requiring 5 days to burn, and yielding with bituminous coal about 40 per cent. of coke.

Coke piles are sometimes made with the flues running across the width of the pile, at intervals of 3 or 4 feet. The flues may be built of large coal, or if this is not at hand, frames of wood like, troughs, having the dimensions of the flue, are placed in the desired position and the intervals packed lightly with wetted coal, after which the frames are removed, being a well defined flue. The piles are finished as already described, but they are lighted by vertical chimneys, formed by a stick stuck in the center of the transverse flues while the pile was building, and which are afterwards drawn out, leaving a vertical chimney, down which lighted coals are dropped.

In England it is the custom when burning in rectangular piles, to construct a longitudinal flue, and in the length of the pile to make vertical chimneys from the flue, by placing stakes at intervals of 10 feet, which are afterwards withdrawn. By these chimneys burning coals may be introduced, and the fire communicated to the center and at many points of the pile at once. The operation is conducted as already described, and when the workman sees that the fire has reached the exterior of the heap at any point, it is immediately quenched by coal breeze. By this construction of pile, they may be made of great size, 100 to 200 feet in length, containing sometimes over 2,000 tons of coal. Their width is usually not greater than 12 feet, and when the coal is particularly impure, they are made somewhat narrower. By lighting them at one end first, the operation may be made continuous for some time, the pile being built at one end, while the coke is removed from the other as fast as it is coked. In burning a heap, it is essential to get the fire to the center as quickly as possible, and then draw it outward toward the surface, as is done in charring wood.

The production of coke in piles will of course vary greatly with the character of the coal, but usually they may be taken to produce from 30 to 50 per cent.

M. Jordan* describes a method formerly employed in the coal

* Album du cour du Metallurgie.

basin of the Loire, France, for coking the very fine coal which could not be coked well in the other forms of heaps.

In plan they are rectangular, while the vertical section is trapezoidal. The fine coal is packed and held in position by a plank covering of suitable size, vertical, longitudinal and cross channels being formed by wooden bars, which are removed when the heap is completed. This process requires great care in the construction of the heap, is somewhat difficult to manage, and is not economical in its results. The yield of coke obtained with the French coals was 50 to 55 per cent.

Coking between walls. A peculiar method of coking between walls was practiced for a long time in Upper Silesia, and afterwards was introduced into Westphalia and France, where it was known as the Schaumbourg Furnace. This furnace, used in Silesia, consists of rectangular walls of masonry, 8 feet wide by 54 feet long, inside. The floor of the enclosure is made of cinder, broken small and well packed, on which fire-brick are placed on edge, thus securing a good drainage and a dry bottom. The inside of the walls are of fire-brick, while the exterior is of common masonry. In each side-wall are built a row of holes opposite to one another, and about 2 feet apart, and from them vertical chimneys open on to the top of the wall. When the kiln is to be charged, one end, is closed by fire-brick, and then through the other fine coal is wheeled in and spread on the bottom, wetted and stamped down in layers until the level of the holes in the walls is reached. Long poles, 6 inches in diameter, are then inserted in these holes, and the kiln filled up by layers of coal stamped down, and the top is covered by a layer of coal-dust. The end wall is then built up and the poles withdrawn, leaving transverse channels in the coal. Before lighting, the vertical chimneys on side are closed by a brick, and the draught-holes on the opposite side are also closed. Fire is then given to the pile by lighted chips, etc., applied at the openings, and from them a current passes out of the chimney in the opposite side. In 6 or 8 hours the fire will reach the other side, when the chimneys on one side are closed and the chimneys on the other side opened, the damper on the horizontal flues being also changed at the same time. By this means the current is reversed, and this is repeated every 2 or 3 hours. Different parts of the kiln are changed, depending on the working of the operation, the

state of the weather, etc. The channels are kept open by a rod, and in ordinary circumstances the operation will be completed in about 8 days, when the openings are all closed and luted, and in 2 or 3 days the end wall is removed, the coke extinguished and discharged. The yield of coke in the furnaces in Upper Silesia was from 50 to 55 per cent.

The principal advantage claimed by the use of this kiln is that it produces a dense and hard coke, bearing transport well, beside which the product is regular and the labor not difficult. It is specially fitted for the carbonization of fine coal. The furnace is not expensive to construct, as near Cologne a furnace to hold 34 tons cost about 3,130 francs ($626).

The charge of coal used in the furnaces erected in the Ruhr and Soar basins was from 7½ to 54 tons, depending upon their size, and the time of coking about 6¼ days, the yield being from 60 to 70 per cent. of coke. Though these furnaces were largely used in Germany in 1850, they are said now to be no longer employed.

In some of those built in the French coal basins, the holes in the side-walls were made at a level with the bottom of the furnace, and their width inside was 6½ feet, their length 19¾ feet, and their height 3¼ feet, leaving a capacity of 18 to 20 tons of coal. The yield of these furnaces with the French coals was from 60 to 65 per cent.

In 1857 the same process was patented in England by Mr. E. Rogers, he believing it, however, to be a new invention, and kilns were erected at various establishments in Wales, where the process had an extended trial. Mr. Rogers considered the best dimensions to be 90 feet long, 14 wide, and 7½ feet high inside, holding about 150 tons of coal. In Wales they were said to produce 75 per cent. of coke, with a saving in working expenses of 50 per cent., besides that the coke was considered more dense and uniform, but all the furnaces erected there on this plan are believed to be now abandoned.

Coking in ovens. The previously described methods are well adapted for coking bituminous coals, possessing good coking properties, but as generally practiced, it requires the larger portion of the coal to be in lumps, or at least not fine. While coal coked in heaps or piles will yield 60 to 65 per cent., the same coal coked in good ovens will yield from 75 to 80 per cent. of coke, which is at the same time of better quality, harder and more uniform. The former method, however, has the advantage of requiring no outlay for expensive structures.

The primitive method of coking in heaps has been to a great extent superseded by the use of ovens or closed chambers of different forms and construction, by which all sizes of coal become equally available. Though the apparatus may be more expensive, the increased yield of coke, its better quality, and the less expense of handling the material cause the cost of the coke to be much less than when made in the open air. A greater proportion of sulphur may be also expelled in the ovens, and coals which would otherwise not coke, or only but indifferently, are made to yield an excellent product. This is specially marked where the uniform and very dry coals are required to be used for coke, and where the expense of the coal requires the greatest economy of material and manufacture. Thus in Belgium, France, etc., the use of the dry and inferior coals, which are commonly washed, has necessitated the employment of ovens specially designed for the circumstances, and thus has arisen the large class of ovens known as the Belgian ovens. From the excellence of their plan, their economy and efficiency, they are now being largely supplied for the better varieties of coal, both in England and this country.

In the production of coke the ovens are almost always heated by the combustion of a part of the coal itself, and in only one or two plans is the necessary heat produced by burning a separate portion on the exterior. When, however, the object in carbonizing the coal is to obtain the gaseous products, as in manufacturing illuminating gas, the coal is heated in a closed retort by fuel burnt beneath it, the operation for obtaining gas solely being conducted in a different manner from that when coke is desired; the coke produced is light, spongy, fragile and unfitted for metallurgical use.

The simplest form of oven for producing a metallurgic coke is a vaulted and closed chamber, like a baker's oven, which is first heated to a high degree, after which the coal is charged, and the volatile matter expelled by the heat of the oven, and being burnt by the admission of air into the furnace, maintains the necessary degree of heat. In this form of oven the coking operation begins at the surface of the coal and descends to the bottom of the charge, and if the heat is insufficient from any cause, coldness of oven, small amount of volatile matter in the coal, etc., the bottom will not be well coked. To facilitate the process, and to use to best advantage the drier or less coking coals, the ovens are heated on the bottom or sides, or on both by the combustion in flues

of the volatile matter of the coal. By this means the coking process acts from different parts of the charge at the same time, and a perfect coking more surely attained. In the construction of ovens, the thickness of the bed or prism of coal in the oven is of the greatest importance. The higher the coking property and the proportion of volatile matter, the thicker may the bed of coal be made, and the lower the degree of coking power, or the drier the coal, the thinner must the prism of coke be made to secure good results. Thus with good coking coals the prism of coal may be 3 or 4 feet in thickness, and then only heated on one side, but with the drier coals, even when heated on all sides, the prism must be much smaller, 3 feet to 27 inches, as in the Belgian ovens. The disregard of this fact is the cause of much ill success in the planning and making of coke ovens. The first and most important consideration is the character of the coal, and the second, the form and size of oven best adapted to the circumstances.

Coke ovens differ very greatly in their form, size, construction and mode of heating, and for convenience they may be divided into two principal classes:

1. Those in which the walls of the oven are *not* heated, and air is admitted into the coking chamber itself to allow the combustion of the gases evolved from the coal, and to maintain the heat necessary for the operation, as in the ordinary "bee hive" oven.

2. Those in which the bottom, the walls, or both, are heated by the combustion of fuel on the outside, generally of the gases from the coal which are burnt in flues in the walls themselves. In some forms the combustion is begun in the furnace itself by the admission of air, as the Jones and Francais oven, but usually it is confined to the flues into which the air is admitted, as in the ovens of the Belgian type.

First Class.—*Bee-hive, Baker's or Round oven.* This is one of the oldest forms of coke oven, and is still used to some extent in France and Germany, where it is known as the English or Baker's oven. In England, however, it is almost exclusively employed, and while it is the most common oven in the United States, large numbers of the improved forms are now being introduced.

A very good example of the bee-hive ovens is in use at the Kemble Iron Co.'s works, Riddlesburgh, Penn.

The ovens are circular vaulted chambers, like a baker's oven, 12 feet in interior diameter, and 6 feet in height from the bottom to the

crown of the vault. They are built of the best quality of fire-brick, the arch being about 3 feet thick, resting on a foundation of masonry. A round hole, 12 inches in diameter, is left in the crown of the arch for charging the coal, and for the escape of the waste gases. A circular cast-iron plate is provided by which this hole may be sealed when the operation of coking is completed. Another opening is left in front about 30 inches square, which is lined with an iron frame, and by which the coke is discharged. The bottom of the oven is formed of a bed, 3 feet thick, of ashes and slag beaten down compactly, upon which a floor of fire-brick is placed, inclining slightly toward the front door. The ovens are built back to back in order to facilitate their charging from the elevated track, which is supported at intervals by masonry piers, so that the weight of the cars does not bear upon the furnaces. A wall of masonry forms the front faces of the furnaces, and the spaces between them and the ovens is closely filled with ashes. The walls are strongly built and bound together by tie-rods to prevent their displacement by the expansive action of the heat.

Water conveyed by pipes is convenient to each oven for the quenching of the coke as it is drawn from the oven. This may be said here to be a most important adjunct to every coking establishment, as water is absolutely necessary to extinguish the fire when the coking operation is completed.

The bee-hive oven of this character as usually built in the United States costs from 300 to 500 dollars per oven, according to the material and method of construction.

The operation is as follows: A charge having been removed from the oven, the walls are at a very dull red heat, the temperature having been reduced during the cooling and discharge of the coke. The fresh charge is made directly into the charging hole at top from the cars by means of portable chutes. The charge is then leveled in the oven by a long poker; the front door is closed by brick-work, and luted, excepting a small space at the top of the door-way, which is left open for the admission of air to consume the gases. At first a dense volume of smoke issues from the opening in the top of the oven, but in a short time the temperature of the oven has risen high enough to ignite the gaseous matter, which then bursts into flame and rises several feet above the top of the oven. The air admitted through the openings in the door-way should be only sufficient to sustain the combustion of

the volatile matter, which burns in the vault of the oven above the bed of coal, and not a little skill is required, especially in stormy weather, to so regulate the admission of air that there shall be no excessive burning of the coal. As long as the distillation continues, and volatile matter is being expelled from the coal, it will be denoted by the flame at the top of the oven. When the flame ceases, the volatile matter has been driven off, and the coking operation proper completed. The front door is now luted up tightly to exclude all air, and an air-plate is placed over the opening in the top, which is covered with ashes to seal it tightly. The oven is then hermetically sealed, and is left to cool for 12 hours, at the expiration of which time the brickwork is removed from the doorway, and the coke quenched by water introduced through a long iron pipe. This quenching of the coke requires a few minutes only, when it is ready to be withdrawn. A small iron bar is placed across the doorway, and held in place by staple on either side, and upon this the workman rests the handle of the long rake or hoe with which he hauls the coke from the oven. This is an exceedingly arduous labor, and requires about 20 minutes for the complete cleaning of the oven. If the coke should not be thoroughly extinguished it is wetted again with water, and then shoveled into wagons by pronged forks, that leave the fine and useless coke dust. The oven having been cleaned, a new charge is then made, as already described. The total time of the operation at Riddlesburgh is usually 36 hours, though it is sometimes prolonged to 72 or 76 hours. This increased time is principally added to the time of cooling, and though the coke is made more dense and hard, the advantage is not always repaid by the increased expense.

The coal employed at Riddleburgh is the Broad Top semi-bituminous coal, similar to the Cumberland. The coal is now washed before coking. The yield of the coal by weight is from 58 to 60 per cent. of coke.

In the region producing the celebrated Connellsville coke, in the vicinity of Connellsville, Pa., the same form of oven is exclusively used, about 11½ to 12 feet in diameter and 6 feet in height. The coal employed is from the Pittsburgh seam, which here has been somewhat metamorphosed, so that it is in fact a semi-bituminous coal. The composition has been already quoted on page 559. It is quite friable in character and readily breaks up into pieces of a small size, leaving little

good merchantable lump coal. The common charge of an oven is 100 to 110 bushels of coal, weighing 76 lbs. or 4 tons; the time of coking, 37 to 38 hours.

This coke is very largely used in Western Pennsylvania, Eastern Ohio, the iron works of Illinois and Missouri, and is even carried to the silver and lead smelting works of Utah, Nevada, etc., where it costs from 25 to 30 dollars per ton. Its value at Pittsburgh varies but little, and is from 6 to 7 cents per bushel, or about $3.50 per ton. It is delivered in most places in Central and Eastern Ohio at a price of from $3.50 to $5.00 per ton, so that often in some localities it is less expensive than the local fuels. The composition of the Connellsville coke has been given on page 559, where it will be seen to contain a high percentage of ash—about 11 per cent. This is too large a proportion for a good iron smelting fuel, and it will probably not be long before some method of purifying the coal will be demanded. The high reputation that it holds is probably due largely to its uniformity, its hardness and fine appearance, though the sulphur present is rarely below 1 per cent.

In England the round ovens are almost the only form used. They are often arranged with an exit flue in the rear part of the vault, for the escape of the gases into a common conduit, through which they pass to a single large chimney, a hole being also left in the center of the roof for charging, but which is closed during the operation. A damper placed in the flue from each furnace, its connection with the main conduit and chimney may at any time be severed.

Furnaces of this type are sometimes made oval, elliptical or rectangular, with doors at either end of the longer diameter for discharging, and an opening in the roof as in the ordinary bee-hive for charging. This form, though once quite common, is now not very extensively employed. At St. Etienne, France, furnaces of this character, with an elliptical hearth, are 15 to 18 feet long, $8\frac{1}{2}$ to $9\frac{1}{2}$ feet wide, and $3\frac{3}{4}$ to $4\frac{1}{4}$ feet high, with an opening in the roof for charging about 18 inches in diameter, and a door at both ends for discharging. The charge of coal is from 2.6 to $4\frac{1}{2}$ tons, and the time of coking 24 to 48 hours, the operation being conducted as in the common bee-hive oven.

A similar form of oven is used at Seraing, Belgium, in which the application of the waste heat of the gases is made to generate steam. They are arranged in a battery of 8 furnaces together, supporting a

80 horse-power boiler, with a chimney at either end, which are used alternately. The charging and discharging is made by the same doors, and as the gas first evolved from the coal has little combustible matter, having much water, it is let escape for 2 or 3 hours through the small side chimneys At the expiration of this time these are closed, and the central one is opened. This has an area equal to the sum of the two others, and through it the gases are aspirated by the main chimney and burn around the boiler. When the boilers need repairing, the gases are let escape by the chimneys, and men may then enter the space around the boiler through arch-ways left for that purpose. One of these batteries of 8 furnaces is said to produce steam sufficient for the blowing engine of a large coke furnace, and by regulating the working of the ovens so that they are discharged at intervals of 3 hours, sufficient heat is always available for the boiler. The charge is 2½ tons, and the time of the operation 24 hours.

The square, anchor, or as it is sometimes called, the Gibson furnace, has been used on the west coast of France for coking the English coals, and is known as the *Boulogne-sur-mer* oven, while it has been used to some extent in Germany and in England, where it originated. The oven is about 12¼ feet long, 6½ wide and 6½ feet in height at the back, flaring a little toward the front, so as to facilitate the discharging. The door is made the full width of the oven, and the coke is withdrawn at once in one piece by the *anchor*, which is placed in the oven before charging the coal. It is hence firmly imbedded in the coke at the end of the operation, and a chain being attached to it, it is drawn out with the coke by means of a capstan. Though it might be urged that the door is too large, causing difficulty in closing the oven tightly, and also that the anchor would rapidly be worn out, in practice, there is said to be no inconvenience from either of these.

The furnace will contain 4 to 4½ tons of coal, which is charged from the front, and the operation is conducted as in the round oven. The gases escape to the chimney by the flue shown in the figure. The time usually required for coking is about 48 hours, and at Doulais furnaces containing 3½, yield 73 per cent. of coke.

In some furnaces erected on this plan in France, etc., small canals are built in the walls, so that at the termination of an operation air may be admitted to them, and the walls cooled down very much before discharging the coke.

A form of the round oven is used in great numbers in France in the Loire basin, in Belgium and in the Soar basin, and is known as the *French furnace.* The furnace is similar to the bee-hive oven, excepting that it has an encircling canal in the walls, which communicates with the interior of the furnace by small conduits, which are highly inclined, converging toward a point near the center of the roof. These canals open to the air by openings on each side of the door, where the admission of air may be readily regulated. The charge is made through the opening in the roof, and the door is then tightly closed, air being only admitted through certain channels. The air is thus supplied regularly in equal portions to all parts of the oven. Though the expense of their construction is somewhat greater than of the ordinary round oven, it is claimed in France that the yield of the coal is increased 6 per cent.

Cox's oven. A form of oven similar to the latter, in so far as air is admitted to the coking chamber through certain canals in the walls of the furnace, is known as Cox's oven. This oven was patented by Cox in 1840, and has been used somewhat in South Wales.

The oven is rectangular in plan, tapering a little toward the door in front, which has the full width of the oven. At a height of 5½ feet the oven is covered by an arch, and a small distance above this is a second arch. The space between these arches communicates in front with the interior of the oven, and at the back with the chimney. Two ovens being placed back to back, they open into the same chimney, which is separated into two flues, one for each furnace. The space above the upper arch and between the ovens is filled with sand, which concentrates much of the heat evolved during the working operation. On one side of the front of each oven an opening communicates with a flue, passing horizontally in the wall to the back of the furnace, where it communicates with the interior by the canals. The charge is made by shoveling the coal in from the front, and then the door is lowered and fastened by an iron bar. The door is formed of an iron frame, which is lined with fire-brick, and when in place is tightly luted to prevent access of air.

The air for the combustion of the gases enters through the canals into the inside of the furnace, when the gases burn and escape into the vault above, and into the chimney. A valve being placed in the chimney flue of each furnace, the draught may be regulated at will

Though the furnace is somewhat expensive in its construction, it is said to have worked successfully, though with some coals the bottom part was not always well coked, as is also the case often with the other forms of ovens of this class. To obviate this, Mr. Parry, of Ebbw Vale, constructed some furnaces on Cox's plan, but the gases, instead of passing directly into the chimney, descended first and circulated underneath the hearth, through flues made in the bottom, which communicated with the chimney; the furnace was therefore heated well on the bottom, and the coal uniformily coked.

Ovens of the Second Class. In the ovens of the first class, as already described, the bed of coal exposed is always of considerable thickness, and the operation of coking is begun from the top, by the heat stored up in the vault of the oven from a previous operation, and proceeds downward to the bottom of the oven. Unless the coal contains sufficient volatile matter to furnish the heat necessary, or the coal is of a strong coking character, the operation will be incomplete and the mass not thoroughly coked. From a too thick bed of coal or too little heat in the oven, a cold or damp bottom, the coking is often incomplete, leaving a stratum of uncharred coal on the bottom of the oven. The ovens of this class are specially adapted for the very best or strongly coking coals, and when the dry or light coals are to be used, the ovens of the second class are better suited, where the prism of coke is thinner and the heat more uniformly applied to the coal, the walls being heated from the interior. In these the coking operation proceeds from the sides toward the center, and when very dry coals are used the prism of coal should be very thin.

The ovens of this class are round and elliptical, as the Breckon and Dixon, etc., or as is more common, rectangular; placed vertically it is the Appolt oven; horizontal, it forms the large class of Belgian ovens. The ovens may only be heated on the bottom, as in the ovens of Panwell, Dubochet, Pernolt, etc., by fuel burnt separately beneath them, which is, however, applied only when the gas evolved is to be further utilized, or the bottom may be heated by the gases from the coal itself, as the Breckon and Dixon oven. More commonly they are heated by flues passing through the walls and under the bottom, in which the gases evolved from the coal burn and produce the necessary heat in the Belgian type of furnace, the Linet, Coppee, Fabry, Francois, Dulait ovens.

The Breckon and Dixon oven, * patented in 1860 in England, con-

sists in constructing ovens similar to the ordinary bee-hive, with flues in the bottom, and admitting the air into the oven itself through flues communicating with the outside. The oven is thus heated on the bottom by the passage of the gases burnt in the oven, and a more uniform, complete and rapid operation ensured.

The interior of the furnace is shaped very like the common round oven. Air is admitted through the dampers in the front on each side of the door to the flues, where it enters the interior, and when the charge is made the door is closed completely, air being admitted only through these openings.

The bottom of the oven is provided with flues, and is formed of fire-brick or tiles resting on the division walls. The gases burnt in the furnace pass through the openings at the rear, and descend through the flue to the canals under the oven bottom, through which they pass back and forth to a vertical flue, and thence to the chimney through a horizontal flue. A damper, placed at the exit of the vertical flue, enables one oven to be shut off from the chimney at any time without interfering with the others. By this construction the floor of the oven is thoroughly heated, and it is claimed that coke may be made in one-third the time that it can be in the common oven, with a yield 10 to 15 per cent. greater. In trials made near Darlington, England, for several years, the coal yielded 69 per cent., while in the common oven the yield was 58 per cent., and a charge requiring 72 hours to be coked in the old oven was completely coked in 48 hours.

Jones' Coke Oven. A form of rectangular oven with the bottom heated was introduced at Dudley, Staffordshire, England, by Mr. Cox.

The entire front being open forms the doorway for the discharge of the coke, while the coal is charged through the opening in the roof. At the rear an opening is left the full width of the furnace, and closed by an iron plate. It is used for affixing the discharging apparatus as described hereafter. At the back of the furnace are two iron pipes or canals, communicating with the exterior, and passing through the chimney. Each of these is provided with a register on the outside to regulate the admission of the air. A canal opens into the rear end of the furnace, just below the arch, while another one rises higher and opens into two flues in the masonry of the top of the furnace, which pass to the front and open into the oven. Two openings in the back of the furnace per-

* Trans. N. England Inst. Mining Engineers, 1860-61.

mit the examination of the two flues. The charge having been made, and spread on the hearth to a uniform thickness, the doorway is closed by a wall of brickwork piled loosely, and a little in front is placed a sheet-iron door, which is supported by a horizontal iron bar. The space between the wall and plate is then filled with coke dust, so as to seal the furnace and prevent the entrance of air. The air necessary for the combustion enters the furnace at the rear through the openings in the back; passing through the flues in the chimney it becomes heated, and enters the back of the furnace and in the front. The volatile matter from the coal is thus burnt in the oven, and escapes by the two openings in the rear of the oven, descends and circulates through the flues in the bottom, and finally escapes into the chimney. The coal used in Staffordshire in the furnace was the celebrated 10-yard seam, a dry coal, the charge consisting of 4½ tons of coal and 1 ton of pitch or tar, which are well mixed between rollers. The time of the operation is 36 hours, when the coke is discharged by an apparatus formed of two cast-iron L-shaped plates, which are riveted to two bars of iron. To place them in the furnace two flat bars of iron are first put on top of the coke, and upon them one of these hoes is shoved to the rear of the furnace; the flat bars are then removed and placed on the side of the oven, and the other hoe is shoved in in the same manner. The ends of the L-plates fall into the vertical space between the rear of the furnace and the coke, which has been left by the shrinkage of the coal during the process of coking. If there is any difficulty in fastening them in this position they are fixed by pokers introduced by the openings in the rear of the oven. The pullers are then fastened together by a bar, and the eoke pulled out at once by a chain and capstan. The yield of this oven when using the materials mentioned is 65 per cent. of coke, which is strong and well suited for iron manufacture.

Of the ovens which are heated by the walls as well as by the bottom, the most important and most extendedly employed are the rectangular ovens, generally of small width, which as a class are known as the Belgian oven, because of the great improvements that have been made with them in that country. In speaking of the development of this type, M. M. Franquoy* says, that in 1837 Walker obtained a patent in England for coke ovens with their bottom and walls heated, which were introduced at Seraing in 1856. The first patent for the

* Progress of Iron Manufacture, Liege, 1861

introduction of air was also patented in England in 1837. Although this was introduced in France and Belgium they were unsuccessful from the manner of introducing the air, and in 1844 Dulait, of Charleroi, Belgium, invented an oven in which the air was introduced in small currents into the encircling flues, which was very successful, and is the plan now adopted in many coke ovens in Belgium. The inducing circumstances in the introduction of these furnaces is stated by Mr. Aug. Sillers, of the School of Mines at Liege * to be, that in 1852 "the extraction of bituminous coal necessary for the manufacture of coke by the means then employed became insufficient in the Charleroi district, and the price increased to such a figure as to threaten serious injury to the iron trade. It was therefore found necessary to economize fuel, and to find means for manufacturing coke out of semi-bituminous (dry) coal, which circumstances were the means of bringing numerous varieties of ovens under notice of the industrial community." Shortly after the same circumstances visited other continental regions, which with their great success, caused their rapid extension. The demands of the railways, about this time on the Continent, requiring the production of a purer and better coke, and its manufacture from inferior and often very dry coals, stimulated the improvements in coal washing and coking, for which we are largely indebted to French and Belgian experience.

Difference of size, arrangement of flues, and other modifications have multiplied the number of this type of ovens, and they are now very largely used on the Continent of Europe, but in England, from the nature of the coal, lack of appreciation, etc., though the type originated in that country, they are used to but a small extent, and have not supplanted the old bee-hive form of oven.

In the United States their good results in quantity and quality of coke has induced their use for not only the drier and less strong coals, but also for the better and stronger coking coals. Ovens of this type are now used in many places in the Allegheny and Missouri coal basins, and their employment is rapidly extending. In the treatment of the coals of the Missouri basin, we have, however, probably to witness their greatest efficiency.

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* Belgian Coke Manufacture, Jul. Iron and Steel Institute, vol. 1, 1873.

CHAPTER VIII.

BUILDING STONES OF OHIO.

FROM ADVANCE SHEETS OF THE REPORT OF THE TENTH CENSUS OF THE UNITED STATES ON "BUILDING STONES AND THE QUARRY INDUSTRY."

[BY PERMISSION.]

[The data for the following report upon the Building Stones and the Quarry Industry of Ohio were gathered in 1880 for the Tenth Census of the United States, under my supervision. The facts thus accumulated have been made the subjects of careful study and arrangement by the appropriate department of the Census Bureau, and the report prepared on this basis is soon to be issued by the General Government. The plan and proportions of this and allied reports were determined by Dr. George W. Hawes, the special Agent in charge of this division of the Census work and Curator of Economic Geology in the Smithsonian Institution, and much of the labor in preparing it was done by him. For such a task, few men in the country were better fitted by natural taste and by acquired knowledge. A recognized authority in lithology, familiar with all the modern methods of inquiry in this field, he has enriched his reports with a considerable amount of special information that is new in kind to the general reader, and that cannot fail to prove stimulating and suggestive to many of our students of practical geology. The work of Dr. Hawes was arrested while still incomplete by his untimely death, but it has been carried forward, chiefly by trusted assistants that he had trained, two of whom went from Ohio and one of whom has been since employed in the Geological Survey of Ohio, viz., F. W. Sperr, M. E. A considerable part of the Census Report on Ohio Building Stones was put in shape by Mr. Sperr, by whom also the geological facts were in large part collected. The chapter is thus largely of his authorship.

The courtesy of Hon. C. W. Seaton, Superintendent of the Census, allows me to use the advance sheets of this report in the present volume. When published by the Government, but a few hundred copies at most will be assigned to Ohio, and its usefulness will thus be greatly restricted, but its adoption in the present volume ensures its wide distribution among those that can turn to the best account the valuable information that it contains.

As has been already stated, its materials were gathered under my personal supervision and have been largely put into shape by one of my assistants, by which facts it is connected closely enough with the Survey, while at the same time, the respon-

sibility of the authorship resting with Dr. Hawes, the value of his special knowledge and his opportunities for a comprehensive review, give to the chapter an authority that it would not otherwise possess.—E. O.]

OHIO.

[Compiled from notes of Professor Orton.]

SANDSTONE.

SUB-CARBONIFEROUS.—Those rocks of the sub-Carboniferous period, called the Waverly group in the *Geological Survey of Ohio*, are the most important as to production of building stone in the geological scale of the state. The following shows the arrangement of this formation, according to Professor Orton:

1. Maxville limestone, in patches.
2. Logan group.
3. Cuyahoga shale.
4. Berea shale.
5. Berea grit.
6. Bedford shale.

No. 1 occurs but seldom. No. 2 consists of fine-grained sandstones overlying and alternating with massive conglomerates in central and southern Ohio. Its thickness is about 100 feet. The Waverly conglomerate is a member of this group. No. 3, about 300 feet in thickness, is a blue argillaceous shale in many parts of Ohio, but in many places contains scattered courses of sandstone of great value. In southern Ohio these are concentrated and become very valuable. No. 4 is from 10 to 30 feet in thickness and is the equivalent of the Waverly black shale of southern Ohio. No. 5 is the Berea grit, the great quarry rock of northern Ohio. It is from 10 to 75 feet in thickness and extends in a belt from Williamsfield, in the southeastern corner of Ashtabula county, westward into Erie county, and thence nearly directly southward in Adams county to the Ohio river. This stratum of sandstone, where it has its best development, consists of heavy sheets with often a course at the top of thin broken layers called shell-rock. However, in many localities these thin layers are unbroken, even, and compact, and are quarried extensively for sidewalk paving. No. 6 is from 10 to 100 feet in thickness, and furnishes no building stone except in Cuyahoga county.

The line of outcrop of the Berea grit across the state from north to south is very near the dividing line between the formations of the Carboniferous age on the east, where the building stone is almost exclusively sandstone, and the formations of Devonian and Silurian ages on the west, where it is almost exclusively limestone.

The Waverly group, with its well-marked alternations of shales and sandstones, enters the state from Pennsylvania in its northeastern corner. The northern line of outcrop of the Berea grit in Ashtabula and Trumbull counties is for the most part deeply drift-covered, and in places it has been cut out by valleys of erosion. From Parkman, in the southeast corner of Geauga county, it can be traced in an almost continuous line of outcrop around to the Ohio river. In Parkman township, as far as exposed, it lies in thin, ripple-marked sheets.

In Mesopotamia, Trumbull county, a quarry of some importance is worked by the Mesopotamia Freestone Company, one mile west of the town center. The stone is used for buildings, flagging, bridges, etc., in the immediate neighborhood, and is of excellent quality. The nearest railroad station is 7 miles away. This company has just taken the contract to furnish the trimmings for the blocks now building at Burton, Geauga county. From this quarry the Berea grit passes northward, and its outcrop may be traced along the line between Geauga and Ashtabula counties to the southeast corner of Lake county, where it turns to the southwest and follows along the line between Lake and Geauga counties into Cuyahoga county.

The Berea grit is quarried at Windsor, in the southeast corner of Ashtabula county. This quarry marks the most northeasterly locality where the Berea grit has any special economic value as a building stone; though even here the stone is much inferior to that to be obtained over quite an extent of country from Berea, Cuyahoga county, westward to Berlin Heights, Erie county. The pyrites and protoxide of iron contained in the stone at Windsor produce bad discoloration on exposure to the weather. As a source of material for heavy masonry this locality is invaluable, as Ashtabula county has no other stone well adapted for this purpose, and the Windsor quarry has furnished a large amount of stone for heavy bridge construction on the railroads and highways in this county. The quarry is located about six miles from the nearest station, and has the same disadvantage as the Mesopotamia quarry for shipping stone.

The most important quarry operations in these counties are carried on in Howland township, 3 miles northeast of Warren, Trumbull county. This stone had been known for many years, and was worked in a small way before the present company began operations. The stone is adapted to the special use of flagging on account of the extreme regularity of its beds, its composition, its strength, and its durability. In evenness of bedding it is remarkable among the quarries of the county. Blocks 10 feet square and $1\frac{1}{2}$ inches thick are extracted, which a straight-edge laid upon the surface would touch at every point. Slabs but 1 inch or 2 inches in thickness have such strength that they go without question into general use. Their fine-grained composition causes them to wear in a uniform manner, and they always give a good foothold. The only defect in the quarry is that the north and south joints do not run evenly; but, as these joints are so far distant from one another as to preclude the possibility of transportation of the included masses, this defect is of but little moment. In one case a single strip 150 feet long, 5 feet wide, and 3 inches thick was raised in the quarry. The layers, although so very closely packed together, are perfectly distinct, adhering to each other scarcely more than sawed planks in a pile.

All the townships in this neighborhood avail themselves of this extraordinary supply of flagging, and the town of Warren is said to be the best paved town in the state; Mahoning avenue may be mentioned as exhibiting on its western side some of the finest flagging that has ever been laid. It has been sent to distant cities in northern Ohio, western New York, and western Pennsylvania, and examples of it may be seen in Pittsburgh, Mansfield, Hornellsville, Akron, etc. It has been used for general building purposes to a limited extent.

The quarries are drained by ditches with a constant good fall. In the flagging deposit proper there are found from four to seven courses, varying from 1 inch to 6 inches in thickness, the 6-inch course being the best and highest priced. The same general character of the stone holds in the adjacent territory, but is subject to some variation of quality. It is of a light gray color, and is the geological equivalent of the stone which is extracted from the Portsmouth and Buena Vista quarries at the southern extremity of the formation on the Ohio river.

The Cuyahoga shales, in which the Austin flag-stones are found, occupy the highest position in the Waverly group in this county, and in the southwestern corner of the county the conglomerate of the Carbon-

iferous formation makes its appearance in a ledge called the Braceville ridge, which rises to 100 feet above the flat surrounding country, and occupies a part of the four townships of Warren, Newton, Braceville, and Lordstown. It is almost entirely destitute of soil, and its prominent points are conspicuously grooved and striated by glaciers. This rock has been the dependence of several generations for building stone in the surrounding region, but no large quantity has ever been extracted at any one time.

Over a surrounding area of 75 square miles whatever stone is used for foundations, well stones, and bridge stones is mainly taken from this ridge. The quarry operations are mainly carried on in the way of "gouging"—that is, in extracting the stone wherever it can be obtained to the best advantage without reference to future quarry operations. Although no quarries are systematically worked, several are in readiness for operation at any time; and it is safe to say that, in the aggregate, $1,000 worth of stone per year is extracted. The material is a strong and enduring sandstone, containing but few pebbles, and is of especial value since the flat country for many miles around is destitute of stone.

The Berea grit is quarried extensively at Newburg and at Euclid, in Cuyahoga county. A quarry has been recently opened on the east side of the Cuyahoga river, near Independence, and the stone has also been quarried at East Cleveland. The smaller quarries have not been considered in the tables.

As a flagging material this stone is considered by many to have no equal in northern Ohio. It is now used almost exclusively for paving the sidewalks of Cleveland and of many other northern cities, especially in the state of Michigan. It is a fine-grained, compact sandstone of a very beautiful blue-gray color when first quarried, a circumstance which caused it to be extensively used for the trimmings of buildings, although its exposure to the weather has frequently modified its appearance. It is not considered safe to use this material for building purposes except for foundations and bridges, as it frequently contains iron sulphide, the oxidation of which produces stains; and when it has not this defect the color due to weathering is not so uniform when the face of the rock is exposed in a wall as when the bed is exposed in a pavement. A greater amount of the sulphide of iron is contained in the stone at Newburgh than in that at Euclid; and it must be added that examples can be cited where the Euclid stone has presented an unmodified appearance after years of exposure in buildings.

The whole stratum of the rock at Euclid is about 20 feet in thickness, and the different sheets are from 2 to 4 feet thick. As a rule the stone is sawed into slabs.

The outcrop of the Berea grit comes from the northeast, and enters the county in Mayfield township. It has no special economic value in the northeast part of the county, but near Chagrin Falls, in the southeastern part, it lies in thin sheets, and is quarried to some extent for flagging purposes. At Bedford it will not compare favorably with the stone from some of the other localities for purposes of building; but it is especially valuable for manufacturing into grindstones, which command a high price in market. That variety of stone which is applicable for grinding springs is especially in demand. The material is a rather coarse grained and homogeneous sandstone, filled with little brown spots of iron oxide. In some portions of the stratum lenticular nodules of this oxide occur from one inch to several inches in diameter, and render these portions worthless; but as they occur only at certain horizons they are easily separated from the better material.

At Independence a stone possessing more of the characteristics of the Amherst stone is quarried, especially applicable for the manufacture of grindstones, although it is used to a considerable extent as a building stone. The material has been used in the city hall and in some other buildings at Cleveland. These quarries are located in a bluff, the outcrop of stone being about 4 miles long and 1 mile wide, and usually covered by a drift deposit from 1 foot to 5 feet in depth, although in some localities the rock is quite bare.

The Berea grit is at this place only from 30 to 40 feet in thickness, and only the top 10 feet have been extensively quarried, as immediately below this there lies a stratum of worthless rock from 3 to 12 feet in thickness. Below this, good material for grindstones and building stones is obtained. This has been little quarried on account of the cost of drainage and that of removing the worthless rock referred to. Only large grindstones, which are best adapted for dry grinding, are manufactured from this material, and it is said that the stones do not glaze when used for this purpose. This stone is especially valued for the grinding of wood pulp for paper manufacture.

The statistics in the tables scarcely give a correct idea of the magnitude of the industry at Independence, as the rock has been quarried in many localities in this bluff besides those now operated.

At East Cleveland the Berea grit becomes 60 feet in thickness; and although it does not possess all the desirable qualities of the Amherst and Independence stones, the Cleveland architects prefer it for foundations on account of its superior strength and its accessibility. It has not been used for any important superstructures in the city, the more excellent stone, before mentioned, being so readily supplied to this point.

The Brooklyn quarries, which are situated just to the south of Cleveland, produce a material which is of about the same quality as that found in the East Cleveland quarries, but the rock is more broken, and is used mostly for foundations and underpinnings. Its broken character allows it to be easily quarried, but large blocks are not so readily obtained.

The largest sandstone quarry in the county is situated in Berea, where an immense amount of material has been extracted for building purposes and for small grindstones. Nearly 40 acres of the Berea grit have here been quarried out to an average depth of about 40 feet. The stratum is from 65 to 75 feet in thickness, and has been quarried to the bottom in but few places. The individual sheets are from 2 inches to 10 feet in thickness, and usually are very even in their bedding. The rock all lies below drainage level and seems to have been but little, if at all, disturbed since its deposition. Joints very seldom occur. The stone is usually soft in the quarry and is very easily channeled. It is of a blue-gray color and a little darker as a rule than the Amherst "blue-stone." A larger portion of the formation here is of the so-called "split-rock" character than at any other locality where it has as yet been quarried, and this characteristic is also more perfectly developed here than anywhere else.

The material is not so applicable for the manufacture of large grindstones as is that obtained in Lorain county, or at Bedford and Independence in this county. Small grindstones can, however, be manufactured more cheaply at Berea, because the rock can be split into thin slabs of any desired thickness with little or no waste. The manufacture of whetstones is also quite extensive.

These quarries produce building stones of an excellent quality, although great care must be taken in the selection of the material, as some of it contains sulphide of iron in such amount as shortly to disfigure the surfaces, even discoloring a portion of the wall below it. The material is, however, carefully graded in such a manner as to distinguish the

good from the bad stone. For bridge-building purposes the Berea stone is considered the best of the sandstones of northern Ohio, since it possesses greater strength. Tests made by J. B. and W. W. Cornell indicated that a $1\frac{1}{2}$ inch cube would withstand a pressure of 15,400 pounds. The Berea stone has been extensively used throughout the whole country, and may be seen in the following: The Merchants' Bank of Canada building, Young Men's Christian Association buildings, and Montreal Telegraph buildings, Montreal, Canada; post-office building, Bank of Montreal building, and the Garland & Mutchinson building, Ottawa, Canada; post-office building, London, Canada; post-office building and Bank of Toronto building, Toronto, Canada; court-house building, Hamilton, Canada; Senator Fessenden's monument; Methodist Episcopal church, Brookline, Massachusetts; New York Clipper buildings, block corner Cliff and Fulton streets, a figure of Christ 10 feet high, and Church of the Transfiguration, New York city; Berea hall, Brooklyn, New York; court-house, Camden, New Jersey; Normal school, St. Agatha's church, and St. Luke's Episcopal church, Philadelphia, Pennsylvania; United States custom-house and post-office, Dover, Delaware; Young Men's Christian Association buildings, Normal School buildings, and Traders' National Bank, Baltimore, Maryland; Baltimore, and Potomac Railroad depot, *National Republican* newspaper building, British minister's residence, and Lewis Johnson & Co.'s Bank building, Washington city; court-house, Napoleon, Ohio; court-house, Marysville, Ohio; Exchange building, Bronson's block, and Madison hotel, Toledo, Ohio; court-house, Sidney, Ohio; Beckman's building, Cleveland, Ohio; court-house, Winchester, Indiana; court-house, Crawfordsville, Indiana; Masonic temple, Indianapolis, Indiana; court-house, Wabash, Indiana; court-house, Noblesville, Indiana; the Ogden block, Dickey block, and McCormick block, Chicago, Illinois; United States custom-house and post-office, Port Huron, Michigan; court-house, Menomonee, Wisconsin; asylum for the insane, Oshkosh, Wisconsin; Cleveland viaduct, representing bridges.

Three miles west of Berea a large quarry is worked, and in the immediate neighborhood three other quarries are situated, which have not been tabulated here because they produce but very little building stone, and the material is almost exclusively manufactured into heavy grindstones. The total value of the grindstones produced from the four quarries was over $10,000 during the census year. Good building stone could not

be advantageously extracted, as the rock is very much broken up. Never more than 12 and usually not more than 7 feet of the rock are quarried, for below this the rock is more broken, and is called "shell rock." The waste products of the quarries are sold for a mere nominal price for foundations and underpinnings. As the rock lies above drainage it is a very desirable material for trimmings on account of the permanency of its color. The grindstones sell for a little above the average price.

Stone quarried at West View is considered equivalent to the Amherst stone.

In addition to the large quarries mentioned, the Berea grit is quarried in a small way to satisfy the local demand. Cuyahoga county forms one of the most important quarry districts in the United States.

Extracting and dressing the Berea grit is a prominent industry in Erie and Lorain counties. The material produced from this and the adjoining regions, under the name of the Amherst building stone, is the most highly esteemed of any in the state, and it has been extensively shipped to Canada. There are large areas of good stone near the surface, away from railroad transportation, which have not been opened. Quite a variety of stones, as regards structure, can be furnished from this formation, increasing the number of uses to which it may be applied.

The Amherst quarries in Lorain county are located in a series of ledges which were once the shore-cliffs of Lake Erie. The elevated position of these stones is a very great advantage, since the light and uniform color seems due to the fact that this elevation produces a free drainage, and the stones have been traversed by atmospheric waters to such a degree that all processes of oxidation which are possible have been nearly completed. The elevation also facilitates the extraction. Spur-tracks from the Lake Shore and Michigan Southern railroad pass through most of these quarries and supply means of transportation, and the C. and F. V. railroad furnishes means of access to those quarries not in direct communication with the above road.

The Berea grit at Amherst, as well as elsewhere, varies considerably in character and solidity within limited distances, and the ledges in which the quarries are situated apparently represent the more massive portions of the stratum, which have resisted erosion and have hence been left in relief.

An idea of the arrangement of the strata in quarries can be obtained

from the following section, which is exhibited in the quarry of L. Halderman & Sons, at Amherst:

	Feet.
Drift material	1 to 3
Worthless shell-rock	6 to 10
Soft rock, for grindstones only	12
Building stone	3
Bridge stone	2
Grindstone	2
Building stone or grindstone	10
Building stone	4 to 7
Building stone or grindstone	12

The floor of the quarry, moreover, consists of good stone, which has been drilled for 12 feet, indicating a still greater thickness of stone which could be extracted.

The other quarries of the region exhibit a similar diversity of material, although the arrangement is not often the same. As regards colors, the stones may be divided into two classes, called buff and blue. The buff stone is above the line of perfect drainage, and in the section above given, this extends as far down as the 2 feet of bridge stone, forming a total depth of 23 to 27 feet. In most of the Amherst quarries the relative amount of buff stone is greater.

As will be noted from this section, the different strata are not applicable alike to the same purposes, and the uses for which the different grades of material can be employed depend principally upon the texture and the hardness of the stone. The softest and most uniform in texture is especially applicable for certain kinds of grinding, and is used for grindstones only, and the production of these forms an important part of the quarry industry. In its different varieties the material is applicable to all kinds of grinding, and stones made from it are not only sold throughout this country, but are exported to nearly all parts of the civilized world. Some of the finest-grained material is also used in the manufacture of whetstones. There are various points in the system of the Berea grit where the stone is adapted to this use, but such a manufacture is best carried on when joined with a large interest in quarrying, so that the small amount of suitable material can be selected; and thus it happens that only at Amherst and at Berea are whetstones manufactured in large quantities.

The stone which is especially applicable for purposes of construc-

tion is also variable. That which is of medium hardness and of uniform texture is used for building purposes or for grindstones; some is too hard or not sufficiently uniform in texture for grindstones, and is used for building purposes only; and the material sometimes found which is difficult to quarry and to dress is used for bridge-building purposes only.

As regards appearances there is much diversity in the material produced in this region. There are differences due to diversity of textures, of colors, and of methods of stratification, yet these are seldom recognized by the casual observer. Differences in color give rise to the terms "blue" and "buff" previously referred to, and differences in methods of stratification give rise to the terms "split-rock", "spider-web", and "liver-rock". The regularly and evenly stratified stone is classified as split-rock; that in which the stratification is irregular and marked by fine, transverse, and wavy lines is classified as spider-web; the homogeneous stone which exhibits little or no stratification is classified as liver-rock. These lines of stratification are frequently marked by the presence of black ingredients which are composed of mica and carbonaceous matter. As regards composition, these stones are mainly a siliceous sand; and analyses show that the dry material contains usually as much as 95 per cent. of silica, with a small amount of lime, magnesia, iron oxides, alumina, and alkalies. When first taken from the quarry it contains several per cent. of water, and as long as this is retained the stones cut easily; upon its loss they harden. Analyses made for the Clough and Columbia Stone Companies show that their stones contained respectively 5.83 per cent. and 7.75 per cent. of water when wet, and 3.39 and 4.28 per cent. of water when dry. The stone is extracted during only eight months of the year, since it is injured by being quarried in the winter and subjected to hard freezing while still containing this quarry water. The winter months are, therefore, occupied in stripping and channeling. The average thickness of this sandstone formation is more than 60 feet in these counties, and in many places, as, for instance, at the Brownhelm quarry, it is over 80 feet in thickness. An acre covered by stone only 50 feet in thickness would furnish over 2,000,000 cubic feet. Many very fine buildings, both in the United States and Canada, have been built of the so-called Amherst stone, among which may be mentioned the Canadian Parliament buildings, and most of the public buildings in Toronto; and there is no city in the Union in which stone is extensively used where

examples cannot be found in which this stone is used for trimmings and ornamental work.

Near Peninsula, in the northern part of Summit county, on the west bank of the Cuyahoga river, is a valuable outcrop of the Berea grit which has been very extensively quarried in the past, and shipped by canal to Cleveland and thence by lake to various lake ports, principally to Buffalo, New York. The base of the Berea grit is here several feet above the canal. The stone is still shipped quite extensively by canal, and also by the Valley railroad. The principal market at present is Akron. About 16 feet of the upper portion of the stratum are used for general building purposes; below this is a 7-foot course, used principally for the manufacture of mill-stones, for hulling barley and other grains; below this, the bottom course, about 5 feet in thickness, is a rather hard material, used quite extensively for paving purposes. The cap-rock is here about 20 feet in thickness; below this the first 6-foot course of building stone contains more protoxide of iron than the Amherst buff, and has a darker color. The remaining portion of the stratum contains less iron, and much of it is almost white.

The Peninsula stone has the reputation of being exceedingly strong, but it is harder and less homogeneous than that from the Amherst quarries.

The Berea grit has two lines of outcrop in Summit county, one on each side of the Cuyahoga river. The one on the east side passes down to Northampton township, where the stratum lies below the drainage level and contains a considerable amount of soluble compounds of iron, and has a very perceptible odor of petroleum, so that the material is not suitable for building purposes. The stratum has not been quarried to the bottom in this locality, but only about 18 feet in depth. The sheets or layers, so far as quarried, vary in thickness from 6 inches to 6 feet. The blocks of stone are mostly sawed into slabs for sidewalk paving. Still farther south, on the west line of outcrop in the northern part of Portage township, a quarry has recently been opened for the purpose of supplying material for sidewalk paving, and some for steps, caps, sills, etc. This material is similar to that in the above quarry, except that so far as quarried in contains no perceptible traces of petroleum.

The exposed strata of rock in Huron county show evidence of great disturbances and displacement. Sharp synclinal and anticlinal axes are

visible in the majority of these exposures, and are most conspicuous in the Berea grit.

In Mr. Perrin's quarry the stratum dips at an angle of nearly 45°. The sheets vary in thickness from 8 inches to 10 feet. This stone is used principally for bridges and foundations. The rock is quarried by first blasting out with powder large masses, which are afterward cut by means of wedges into the sizes required.

In Mr. Grannell's quarry the rock has been less disturbed and lies in nearly a horizontal position. The sheets here are not so heavy as in the above quarry, but the quality of the material is about the same. The layers vary from 1 inch to 5 feet in thickness, and those 6 inches and less in thickness are used principally for paving purposes. The thinner sheets are raised from their bed by means of wedges and bars.

Still farther south in this county, in Fairfield and Greenfield townships, the stratum of the Berea grit is made up almost entirely of thin sheets.

In a quarry in the latter township the sheets vary in thickness from 1 inch to two feet, the prevailing thickness being from 1 inch to 6 inches. The material is used almost exclusively for paving purposes, for which it is well adapted, being strong and durable, though much of it is deeply ripple-marked and does not make a smooth pavement.

The line of outcrop of the Berea grit formation is marked by a series of quarries which cross the eastern tier of townships in Crawford county. (*a*) The quarries in Polk township are at present of much less importance than those in Jackson township in the vicinity of Leesville. Quarries have been worked in this vicinity for thirty or forty years. The quarry of the Leesville Stone Company is located about one mile north of the railroad station, but a spur-track is now nearly completed from the main line of the railroad to the quarry. The material from this quarry has earned a good reputation, and the stone has been quite extensively extracted during the last few years. The rock lies below the level of perfect drainage, and in both color and texture it is similar in appearance to that quarried at Berea, but on exposure to the weather its color changes to light gray. Blocks of any desired dimensions may be obtained in this quarry, and the method of quarrying is the same as that employed in the Berea and Amherst quarries. The material is employed for all general building purposes, most extensively, however,

(*a*) Geological Survey of Ohio, Vol. III, p. 321; "Geology of Richland County," by M. C. Read.

for the construction of bridge abutments and piers. It finds its principal markets along the line of the Pittsburgh, Fort Wayne, and Chicago railroad, from Crestline westward into northern Indiana. This quarry is locally more important from the lack of building stone suitable for heavy masonry along this portion of the railroad. Other quarries less favorably located are worked, some with considerable variation in quality, but furnishing material for local use.

In Plymouth township, in the northwestern corner of Richland county, the Berea grit is quarried for the construction of foundations and bridge work in the vicinity of the quarries. Some flagging material is also obtained from the quarry of Mr. Bevier. The material developed in this locality is inferior in quality to the Leesville stone, and on exposure to the atmosphere it is more liable to suffer detrimental discolorations.

The Waverly conglomerate furnishes nearly all the stone for ordinary purposes of construction in the town of Mansfield. In one quarry about 60 feet of rock is exposed. It is considerably broken up; the upper 30 feet being in thin layers, and the lower 30 feet in layers from 1 foot to 6 feet in thickness. Much of this material is beautifully colored in wavy bands of black, yellow, red, and gray, and would make a very ornamental stone if it were not so soft and easily worn by abrasion. It has been used to some extent for purposes of ornamentation in the town of Mansfield. In some of the colored material the red predominates, and the stone is harder but less beautiful in appearance, but it does not exist in large quantities. In another quarry the material is less broken up, and is more uniform in quality, texture, and color.

The Waverly conglomerate in this locality is a coarse-grained sandstone, but rather finer than in most other localities where it is quarried. The light-red and gray-colored samples forwarded to the National Museum were found to be very good and safe stones to work. The dark-red colored specimen is rather coarse and loose in structure.

A section of the quarry of Mr. D. W. Zent, at Belleview, exhibits the following arrangement of strata: (*a*)

	Feet.
1. Earth	2 to 4
2. Coarse pebbles of drift	8 to 10
3. Sandstone in thin layers	15
4. Sandstone in massive layers	8
5. Sandstone in layers of 1 foot to 4 feet	15

There is but little variation in the character of the material except in color. The material has been used principally in the construction of railroad bridges on the Chicago branch of the Baltimore and Ohio railroad. Considerable of the material is used at Lexington, Ohio, and in the neighborhood of the quarry. Only a small amount of powder is used in the extraction of the stone, and the amount of production is controlled by the demand for stone by the Baltimore and Ohio Railroad Company. The layers of stone are from 6 inches to 6 feet in thickness, and open joints occur from 4 to 5 inches in width. About 60 feet of rock are exposed in the quarry at the present time, and the formation has not yet been quarried out to the bottom. The color of the layers near the top of the quarry is brownish; farther down some of the stone has a yellowish appearance, and at the bottom of the quarry is a layer of mottled or clouded stone, a blending of red and brown.

An abundance of stone of indifferent quality may be obtained in the vicinity of Wooster from the Waverly formation. A little north of the town a much-broken sandstone is quarried to some extent for the production of material for building foundations and cellar walls.

The most important quarry in this locality is in the Waverly conglomerate. In this quarry blocks of any desired dimensions may be obtained, and the stone is used principally for the construction of foundations and bridge work. At the joints the material shows a discoloration to a depth of about 1 inch, due to weathering. A quality of material rather superior to the above is obtained from the Carboniferous or Sharon conglomerate in Chippewa township, in the northeastern part of the county.

In the quarry of the Walnut Grove Stone Company, operated here, large blocks are obtained for bridge-building purposes, and some of the material quarried is used for the construction of foundations. The principal markets for the material are at Orville and Wooster, and some is transported to Akron, in Summit county. The material is a coarse-grained though quite firm and durable sand rock, very suitable for heavy masonry. At the natural joints in the quarry the material shows but little discoloration from the effects of weathering. The marketable material here comes almost to the surface; it is necessary to remove only about 3 feet of drift material before the marketable product is reached. The material is quite soft when first quarried, but hardens upon losing the quarry water.

The stratum in which the quarries near Massillon, Stark county, are located, according to the concurrent testimony of all the geologists of the Second Pennsylvania geological survey, is the second or middle sandstone of the great Carboniferous conglomerate; it immediately overlies and often cuts out the lowest coal, known as the Sharon seam. Dr. J. S. Newberry, in the *Report on the Geological Survey of Ohio*, confines the designation of Carboniferous conglomerate to the Sharon conglomerate which lies below the Sharon coal. The Massillon sandstone, in the quarries near the town of Massillon, is quarried by means of channeling and wedging. The courses vary in thickness fron 2 to 8 feet, the lower courses being the thickest. The stratification is somewhat undulating, and the courses are not uniform in thickness. Blocks of stone of any desired dimensions may be obtained from any of the quarries devoted to the production of building stone. The entire thickness of the stratum is about 60 feet. This material is employed principally for general building purposes, but it is also manufactured into grindstones, chiefly for dry grinding. According to the testimony of Mr. J. P. Burton, of Massillon, the Massillon sandstone, when subjected to a temperature of 900° F., yet remains in perfect condition. He has used the material for many years in his furnace-stack at the Massillon blast-furnace; and the stone which stood the above test was taken from the quarries of Messrs. Warthorst & Co. and used for a hearth. The texture of the stone is not the same in all the quarries about Massillon, and the finest-grained material is obtained from Mr. John Paul's quarry, about 5 miles north of the town. The upper layers in this quarry are crushed for glass-sand and the lower layers for steel-sand, and but little of the material is used for purposes of construction. Powder is used for removing the cap-rock, which varies in the different quarries from 2 to 10 feet in depth, and for extracting the material for glass and steel-sand.

All three horizons are worked for the Youngstown market. The Briar Hill and Bear Den quarries belong to the middle horizon, and those of Austintown to the highest. The ledges in this locality, as a rule, grade upward in fineness, and the upper stones give the best results when dressed. All of them are nearly pure silex, and the waste material of the Briar Hill quarry is all ground or crushed and sold to the steel works; much of it is adapted also to coarse-glass manufacture. The rock of the middle ledge is colored in bands and lines with iron perox-

ide, which robs it of beauty, but interferes in no way with its durability. In all northeastern Ohio there is no limit to the amount of strong, massive, and durable building stone to be obtained. The quarries in the middle division of the Conglomerate series, on account of the more favorable situation of the outcrops, are more largely worked than the quarries in the upper and lower divisions.

The Austintown quarries have been worked at intervals since the country was settled. The stone is light-brown in color, rather coarse, but uniform in texture. It is used to some extent for purposes of ornamentation in Youngstown, but its principal uses are for general building purposes and bridge work. Flag-stones of fair quality are also quarried here for the local demand, from a horizon just below the sandstone ledge. Blocks of any desired dimensions may be obtained from the middle division of this series, and the material is used principally for general building purposes, bridge work, and to a small extent for ornamental fronts. The principal market for all these quarries is Youngstown. Some material is shipped from the Briar Hill quarry to Pittsburgh and some is used for purposes of construction by the New York, Pennsylvania, and Ohio railroad.

Stone for local uses may be obtained almost everywhere in Tuscarawas, Holmes, and Knox counties, and for this reason no extensive quarry is worked. A quarry was opened and developed for the purpose of extracting material for bridge construction on the line of railroad running near the quarry, but is now nearly abandoned, because this railroad obtains building stone in cuts through the same stratum. This stone lacks the uniformity of texture and color demanded for the better class of work.

There are a number of ledges of sandstone, about 20 feet in thickness, found at different horizons in the Lower Coal Measures in Tuscarawas county, and they all furnish some building stone. A considerable portion of the building stone used in the county is obtained from masses of rock which have been detached from the solid ledges. The stone from the quarry of the Tuscarawas Valley Coal and Iron Company is finer in texture and of a more uniform color than any other stone obtained in the county. It is used for "bottom" in the blast-furnace belonging to this company, and resists the action of heat uncommonly well. The principal uses of the material from these quarries are

for constructions of foundations, underpinnings, and bridges in the vicinity in which the quarries are located.

Almost everywhere in Holmes county there are lying on the surface large masses of rock which have been detached from the strata of the Coal-Measure sandstones. These detached masses supply the local demands for building stone, and no quarries are developed in the ledges.

Near the central part of Knox county, from 3 to 7 miles northeast of Mt. Vernon, large masses of rock lie loose upon the surface. These have not been transported to their present station, but have been left in loose blocks on the surface by the undermining and removal of a portion of the soft shales that immediately underlie the stratum of sandstone. The quarry operations represented by Messrs. Bartlett Brothers are worked in these masses of sand-rock. This stone is considered the best material for building purposes to be found in the vicinity of Mount Vernon. It is used for all general building purposes, including caps, sills, columns, etc., in the town and through the neighboring country. It is estimated that about 250,000 cubic feet may be obtained in some places from the surface of half an acre in area. This material has been a source of local supply for about seventy years.

The Waverly conglomerate, which is quarried near Howard station, is not so highly esteemed as is the stone of the Carboniferous conglomerate, described above. The demand for it is principally for use in the construction of railroad bridges, arches, culverts, and to some extent for foundations and underpinnings. Some is shipped to Columbus, Ohio. The layers of stone in this quarry vary in thickness from 6 inches to 6 feet, and blocks of any required dimensions may be obtained. It is rather soft when first extracted, but hardens on exposure to the weather.

In Morrow county the Berea grit crops out, and is quarried in North Bloomfield, Washington, Gilead, and Lincoln townships. Its total thickness varies from 15 to 40 feet in different localities. The thin layers of its upper portion are very even and compact, and make an excellent flagging material. The most favorable development of the flag-stone occurs near Iberia. At this place the layers vary in thickness from 1 inch to 6 inches, but 2½ inches is the most common thickness; the total depth of flag-stone is about 20 feet, below which from 18 to 22 feet of heavier layers occur. The quarries are located in

the bed of a stream, and only the thin layers are extracted. The amount of flag-stone that may be quarried in this vicinity is practically inexhaustible. At present the material is carried on wagons 2 miles to the nearest railway shipping-point, and a considerable portion of the product of the quarries is carried on wagons to the town of Galion, in Crawford county, which is the principal market for the stone quarried in the northern part of Morrow county.

The thickness of the heaviest layers in the county is only about $2\frac{1}{2}$ feet.

The Berea grit crosses the eastern part of Delaware county, and at Sunbury quite important quarries have been developed. It has here been worked to the depth of about 20 feet, as deep as natural drainage is available. Good building stone might be obtained below this depth, but artificial drainage would be required. This material bears a close resemblance to the Euclid "blue-stone" of northern Ohio. The layers vary in thickness from 3 inches to 3 feet. The thin layers are quarried for flagging stones, and the heavy ones for general building purposes and to some extent for ornamental work. The material finds its principal markets at Delaware, Mount Vernon, Columbus, and Orrville, Ohio. Examples of it may be seen in the building of the Ohio Industrial Home for Girls in Delaware county, and in the National Bank building at Delaware.

The sandstone of the Berea grit in the eastern part of Franklin county has considerable local value, because on each side of its outcrop the surface of the country is occupied by a belt of shale from 8 to 10 miles in width, the belt on the west being entirely destitute of building stone and the one on the east is nearly so. The formation has, however, in this part of the State lost many of the valuable qualities which characterize it in Erie, Lorain, and Cuyahoga counties. On account of its accessibility, however, it has been used quite extensively in Columbus, the Ohio Institution for the Blind being constructed of it as well as several stone fronts.

The entire product of a quarry 10 miles east of Columbus is sawed at the quarry for caps, sills, ashlar, etc., and shipped to various points along the lines of the Baltimore and Ohio and Pan-Handle railroads, but principally to Columbus.

The greater portion of the surface of Licking county is occupied by the rocks of the Waverly formation, but a portion of the eastern

part of the county is occupied by the conglomerate and Coal-Measure rocks. The Waverly conglomerate crops out in bold cliffs over quite an extensive area in Madison and Hanover townships. It has been quite extensively quarried in this vicinity for use as material for construction on the lines of railroad running through this section of the county. It is a rather coarse-grained sandstone, in some localities quite uniform in texture, and in others containing pebbles sometimes an inch in diameter. It is rather soft when first quarried, and works rather easily, but hardens on exposure. In some places sections of this conglomerate 100 feet in thickness are exposed in ravines. The quarries now operated are located in the banks on each side of the Licking river. One quarry is located in the north bank, at the foot of which runs the Ohio canal, which furnishes the means of transporting the material to Newark and Columbus, where it finds its principal markets. Another quarry is located in the south bank, at the foot of which passes the Baltimore and Ohio railroad. The material is used quite largely for heavy masonry along the lines of railroad, and for general building purposes at Newark and Columbus. It varies in color from gray to light brown. The cap-rock necessary to be removed seldom exceeds 4 feet in depth, and consists principally of soil, loose sand and gravel.

This material may be obtained with equal advantage on the line of the Pan-Handle railroad, and there is no limit to the amount of strong and durable sandstone which may be extracted in this vicinity. A quarry 1½ miles south of Newark, in the Cuyahoga shale, furnishes a fine-grained and homogeneous material, at present used principally for foundations at Newark and Columbus, Ohio. Trinity church, at the latter place, was constructed of this material, and the only defect noticed in the stone is the discoloration. It gives evidence of both strength and durability when laid on its natural bed and when it is quarried sufficiently early in the season to allow it to become thoroughly dry before being subjected to the action of frost.

The Waverly sandstone seen in Fairfield county in the cliffs along the Hocking river is generally coarse-grained, often passing into a true conglomerate; and it shows the same character in the hills and highlands west of the river. It is more commonly of a rich yellow color, but sometimes of a darkish brown. In many places the stone is firm in texture and capable of resisting great pressure without crushing. (*a*) The stratum in which the quarries near Lancaster are worked is

(*a*) Geological Survey of Ohio, Vol. III, p. 594.

solid, and about thirty feet in thickness. There are but few joints, and the largest sized blocks may be obtained. The material is used principally for bridge construction, canal locks, and general building purposes. The principal markets for this material are Columbus, Centerville, and Lancaster, Ohio. The material for the superstructure of Saint Joseph's cathedral at Columbus was obtained at the quarry of Messrs. Sharp & Crook, and that for the foundation of the same structure from quarries in the Waverly conglomerate near Hanover, Licking county. The amount of cap-rock to be removed is from 3 to 4 feet in some localities, and as much as 25 feet in depth in other places. Powder is employed in quarrying.

The Lithopolis quarries are located in the lower portion of the Cuyahoga shale of the Waverly group. There are several horizons of building stone in the Waverly group, but this particular portion of the Cuyahoga shale is quite rich in quarries, especially in southern Ohio. There is a number of important quarries in the upper member in different parts of the State, as indicated in the tables. The lower portion of the Cuyahoga shale has no economic importance in the northern part of the State. The only important quarry in the whole formation in northern Ohio is that of the Austin Flagstone Company, in the upper portion of the shale. In southern Ohio the most important building-stone quarries are in the lower portion of this shale.

The stone quarried at Lithopolis and at other localities at or near the same horizon is commonly denominated freestone. It is a fine-grained sandstone, usually in quite thin courses; is sawed easily, and answers a very convenient purpose for caps, sills, and stone fronts. Columbus, Ohio, is the principal market for the product of the quarries.

Stone for the ordinary purposes of construction may be obtained in various localities in Hocking county, but only one quarry is developed in the Waverly conglomerate near Logan, and the material from this has but recently come into the market through the facilities for transportation afforded by the construction of the Hocking Valley railroad. There are no important quarries below this point in the Hocking valley. The stratum of the Waverly conglomerate in this locality consists of three layers, each about 10 feet in thickness. The rock underlies an area of four or five acres with a cap-rock but a few feet in depth, consisting of clay and gravel, which is easily removed. The quarry is located close to the railroad and is capable of supplying any demand

for material likely to be made upon it. It finds its principal markets at Columbus, Lancaster, and London, Ohio, and has been shipped to some extent to Marion and Winnemac, Indiana.

When a canal was constructed through the valley fifty years ago, it furnished easy transportation for the great ledges of sandstone that bound the valley for a dozen or more of miles, and the stone from Waverly, Pike county, soon became famous in Columbus and central Ohio generally as Waverly stone. The name was early extended to a great group of associated sandstone and shales of sub-Carboniferous age, as has recently been proved, but the real age was long an unsettled question; hence comes the Waverly group of Ohio geology. It is the first sandstone, except the local Euclid blue-stone, reached in ascending the geological scale of Ohio that can be quarried. The stratum is best shown from Waverly south for 10 or 12 miles. It dips below drainage just south of the county line on the river's bed. For these 10 or 12 miles it is reached on all the ravines on each side of the river. The stone about Waverly has been followed back under such heavy cover that the increased expense of quarrying has ruled the material out of the market. A quarry at Piketon has just been made possible by the Scioto Valley railroad, constructed four years ago. There is, however, no first-class stone now available in this quarry. There are 26 feet exposed in it in courses varying from 1½ to 24 inches in thickness. There is a great amount of reliable stone in the stratum and a great amount that is treacherous. It is by no means equal in uniformity of quality to the Berea stone of northern Ohio. It formerly furnished a grindstone grit of great local value. The stone is always ripple-marked and bears other evidence of having been formed on a shore-line. It is usually of a uniform gray color, but there is also a variegated variety clouded with red which is one of the most striking stones of the State. The above, however, is but an inadequate statement in regard to the range of quarries that for many years held the first place in southern Ohio. Many other ledges of at least equal value have now been rendered available by the new lines of railroad communication.

The Waverly stone, where it has not been subjected to atmospheric influences, has the characteristic bluish-gray color of the Berea grit formation in other parts of the State. The difference in composition between the weathered portion and the blue-stone is shown in the following analysis made by Professor Wormley for the *Report on the Geological Survey of Ohio:*

	No. 1 (white-stone).	No. 2 (blue-stone).
	Per cent.	*Per cent.*
Silicic acid	91.30	91.00
Protoxide of iron	0.86	1.17
Sesquioxide of iron	0.06	0.30
Alumina	5.79	5.20
Lime	Trace.	Trace.
Magnesia	0.32	0.28
Water, combined	1.30	1.80
Total	99.63	99.75

Near Cynthiana, where the variegated variety above referred to occurs, there is also found a very white, fine-grained variety, and the following analysis shows this to be very nearly of the same composition as that above, without the oxides of iron:

	Per cent.
Silicic acid	91.35
Iron, sesquioxide	Trace.
Alumina	6.00
Lime, carbonate	0.75
Magnesia, carbonate	0.34
Water, combined	1.00
Total	*a* 99.44

The Waverly brownstone quarries lie at a horizon about 40 or 50 feet above the Waverly stone, or Berea grit, in its southward extension. They lie very near the horizon of the famous Buena Vista stone of Scioto county. A number of the best stone fronts at Columbus, Ohio, have been constructed from the product of these quarries. The stone is brown only on the outcrop; when found a few feet under cover it assumes a dark blue color and loses its value as an ornamental stone. The blue variety contains a large amount of soluble iron protoxide which produces a bad discoloration on exposure to the atmosphere. The following analysis made by Professor Wormley for the *Report on the Geological Survey of Ohio* shows the composition of the Waverly brownstone:

(*a*) Geological Survey of Ohio, Vol. II p. 623.

	Per cent.
Silicic acid	73.90
Protoxide	......
Sesquioxide of iron	13.44
Alumnia	8.56
Lime	Trace.
Magnesia	0.46
Water, combined	3.30
Total	99.66

The quarry which has been the most important is located about half way between Waverly and Piketon. Here the stone forms a massive bed 8 feet in thickness. The same ledge has been worked along the valley on both sides of the Scioto river for 10 or 12 miles. That quality of stone still remains in easy reach, though some of the quarries have already yielded all their brownstone to the market. The depth of cap-rock to be removed in these quarries nowhere exceeds 15 feet.

All the ravines that reach the Ohio valley below Portsmouth for 20 miles disclose a large amount of excellent building stone, but in the ravines that are found from 2 to 4 miles below there is a horizon disclosed that lies low enough to be easily reached, and that is naturally covered by an easily-eroded cap, so that a very considerable amount of building stone has been found readily accessible. This horizon is at about the middle of the sub-Carboniferous system in Ohio.

The Portsmouth quarries have been worked since the first settlement of the Ohio valley. During the last fifty or sixty years a great number of separate quarries have been opened, but all on the same horizon. When the stripping becomes heavy a slight change in location is made. The land is considered of no great value for any other than quarrying purposes. Some locations prove better than others, and these are being worked more systematically of late years.

At the quarry of Messrs. Reitz & Co. the stone occurs in layers from 6 to 24 inches in thickness. These courses are frequently separated by an inch or two of shale. Joints do not occur frequently to interfere with the systematic working of the quarries. For flagging the stone is unequaled in the Ohio valley, as it wears evenly, always gives foothold, and is in every way satisfactory. It is well adapted to sawing, and is used quite extensively for general building purposes. The material finds its principal markets along the Ohio valley, through Ohio,

West Virginia, Kentucky, and Pennsylvania. It has been used in the construction of the court-house at Athens, and the Children's Home building at Gallipolis, Ohio, and the Western Penitentiary of Pennsylvania, at Allegheny.

The quarry of Mr. J. M. Inskeep is located about 12 miles below Portsmouth, on the Ohio river, at a horizon about 60 feet above the Buena Vista stone proper. There are 30 feet of rock in about 20 different layers. The lowest course, about 32 inches in thickness, is the most valuable stone. This course is covered by 4 feet of blue shale, which is the largest mass of shale in this section. The other shale deposits are but little more than partings between layers of sandstone. The courses are remarkably even in thickness, but those above the lowest do not yield a strictly first-class material. For the last three or four years this quarry has supplied material most extensively for the Columbus market, and a number of fine stone fronts have ben constructed from it. The stone varies considerably in quality, and needs to be carefully inspected.

The southwestern portion of Scioto county and the southeastern corner of Adams county, two adjoining districts, were once the most important localities in Ohio for the production of building stone. In the earlier days of the state an engineer of reputation, employed upon the construction of canals, became conversant with the then known building stones of the state, and recognizing the great value and accessibility of the ledge, commonly known as the Buena Vista Freestone ledge, bought a large territory here, and began the development of the quarries in a large way. Other horizons of good rock were found at various levels, but this one bed, by its color and quality, supplied the Cincinnati market almost exclusively. Its reputation spreads throughout the whole Ohio valley and beyond. Large quarries were opened on both sides of the river, government patronage was secured, and material for the construction of custom-houses and other public buildings was ordered from the Buena Vista quarries. So great was the demand for this stone that material of poor quality as well as good was hurried into the market. The green stone while full of quarry water was laid in massive walls, and the bad behavior of this material soon excluded the stone almost entirely from the market. It is, however, as good now as when it earned its high reputation, but needs careful and conscientious selection and suitable seasoning.

ust below the horizon of the Buena Vista stone lies the Berea shale, a bed of highly bituminous and very fossiliferous black shale, ranging from 15 to 30 feet in thickness. Its bituminous composition makes it a source of petroleum, which rises into the sandstone courses that lie above it. This is the source of one of the worst impurities of the Buena Vista stone. When followed under cover it is found loaded with petroleum or with tar, which seems not only to disfigure the stone but to weaken it to some extent; and other impurities in the stone are masked for the time by this bituminous matter. The oil-bearing stone is tolerated only in rough, heavy work. Some of the stone contains sulphide of iron, which, on exposure of the weather, becomes oxidized to the sulphate and goes into combination with compounds of aluminum, and appears on the surface of the stone as a white efflorescense which has the characteristic taste of alum. Grains and nuggets of pyrites appear in the shales associated with this sandstone, but are not very perfectly visible to the naked eye in the city ledge (the name now applied to the stratum proper of Buena Vista stone). The rock is quarried by channeling and wedging in the same manner as in the quarries of the Berea grit in northern Ohio. No stone is extracted for the market during the winter months, but this time is occupied in removing the cap-rock and in channeling. The behavior of the material when properly selected is apparent in a number of important structures in Cincinnati, and that of the unselected material may be seen in the custom-house and other buildings in Chicago. The material has also been used with good and bad results in a number of other cities and towns, including Louisville, Kentucky, Pittsburgh, Pennsylvania, and Detroit, Michigan.

CARBONIFEROUS.—The Carboniferous conglomerate (Sharon conglomerate of the *Second Geological Survey of Pennsylvania*) furnishes the only important building stone in Portage county. This formation in Ohio geology is commonly called "the Conglomerate."

In Franklin, Mantua, and Nelson townships, where it is well seen, it is a coarse, drab-colored sandstone, in places thick set with quartz pebbles from the size of a pea to that of an egg. It is quarried in these localities to a small extent for local purposes.

At the quarry of Messrs. Case & King, in Windham township, it is finer, whiter, and more homogeneous, and answers quite well for architectural purposes. It is rather too coarse for fine work, but it is strong

and durable and well adapted to bridge building and all other plain and massive masonry.

In Summit county the Carboniferous conglomerate underlies all the higher portions of the county and forms the surface rock over all the middle portion, except where cut through by the Cuyahoga and its tributaries; though generally covered and concealed by beds of drift, it is exposed and quarried in all the towns north of Akron. In the valley of the Cuyahoga it forms cliffs sometimes 100 feet in perpendicular height. The rock is about 100 feet in thickness, generally a coarse-grained, light drab sandstone, but in some localities, and especially near the base of the formation, becoming a mass of quartz pebbles, with just enough cement to hold them together. (*a*)

All the accessible material that is now known in this formation is applicable to ordinary purposes of building. Although it is quarried in many different localities for local supply, it is worked extensively in but two localities—at Akron and in Twinsburg township. The quarries at Akron are worked principally to supply the town with foundation stone and the immediate vicinity with bridge stone. The quarries in Twinsburg township are at present worked quite extensively to supply material for the construction of bridges on the Cleveland and Pittsburgh and the Connotton Valley railroads.

A section in Mr. Parmelee's quarry exhibits 18 inches of soil and gravel, 15 feet of coarse sandstone in which thin strata of pebbles occur from $1\frac{1}{2}$ to 4 feet apart, and 6 feet of very coarse conglomerate underlaid by shale. The 15-foot course of sandstone occurs in a solid mass, which separates easily where strata or sheets of pebbles called "bed-seams" occur. In the Akron quarries the stone is fine-grained and more homogeneous than in the Twinsburg quarries. In Mr. Hugill's quarry the rock has been quarried to a depth of 40 feet, and the material obtained is a coarse-grained sandstone free from pebbles. Formerly, in a quarry known as Wolf's quarry, near Akron, a local stratum produced a deep reddish purple sandstone, perhaps the most beautiful building stone ever produced in the state, which was used quite extensively in Cleveland, and two residences on Euclid avenue are constructed of this material. At Cuyahoga Falls a similar material has been quarried to some extent for the construction of buildings in the town. The quantity of this variety of building stone is apparently not large, and it seems that it is

(*a*) Geological Survey of Ohio, Vol. I, p. 212: "Geology of Summit county," by J. S. Newberry.

nowhere known at present where it can be profitably quarried in a large way. The Wolf quarry has not been worked for a number of years.

The stone quarried for building purposes in Coshocton county is obtained from blocks detached from strata of sandstones of the Lower Coal Measures. The stratum from which the blocks quarried by the parties represented in the tables have been detached is a solid ledge 30 feet in thickness, and lies a few feet above the horizon of the Zoar limestone. The material is usually a light-colored sandstone, though some of it has a reddish color, and some is a finer-grained white sandstone. The stone used for the construction of locks on the Ohio canal, through Coshocton county, was obtained from these quarries. The stone has the reputation of enduring well ordinary atmospheric influences, but not of withstanding a high degree of heat. It is principally used for bridge building and foundations in the vicinity of the quarries.

Material for the ordinary purposes of construction is obtained in various localities in Muskingum county from the Coal-Measure sandstones, but there is no extensive quarry at any place except about half a mile east of Zanesville. This quarry furnishes by far the largest part of the stone used for construction in and about Zanesville. It has been used quite extensively for building canal locks, foundations, and for sidewalk pavements. Some of the oldest buildings in Zanesville are constructed entirely of this material, and it is found that the stone is more capable of resisting atmospheric agencies than of resisting the abrasive action to which it is subjected in sidewalks. This material is easily obtained in great abundance and of fair quality, and is the most important among the building stones found in the neighborhood of Zanesville. The most conspicuous use yet made of the stone is in the construction of the new Court House of Tuscarawas county. It has here been found susceptible of ornamentation to a marked degree.

The most important building-stone quarry in Noble and Guernsey counties is near Cumberland, on the line between the two counties. The stratum quarried is solid and about 10 feet in thickness. The material is a dense, fine-grained sandstone, rather hard, but susceptible of being finely carved. It is of a gray or light-brown color where it has been subjected to atmospheric influences, but as the excavation progresses into the hill a material of bluish-gray color is obtained. Joints in this stratum are filled up with a hard calcareous matter deposited from solutions of the material from a limestone ledge a short distance above the

sandstone. The size of blocks determined by these joints is about 30 by 15 by 10 feet. The material is employed for all general building purposes, principally at Cambridge. It is used in the superstructure of the court-house in process of construction at this place. The foundation stone for this building was obtained near Cambridge, from a quarry worked only to supply temporary demands.

Stone for the ordinary purposes of construction may be obtained in various localities in Jefferson county from the different sandstone strata of the Coal Measures, which occupy the whole area of the county; but the only quarries that have been developed are those near Steubenville, in the Upper Coal Measures.

One quarry furnishes stone for general building and paving purposes, used principally in the town of Steubenville. The material has a bluish color where it has not been exposed to atmospheric action, and at the natural joints discoloration has penetrated into the rock from 10 to 18 inches. This liability to discoloration makes this stone unfit for the finer purposes of construction.

A better material for purposes of ornamentation is obtained from the quarry where two separate and distinct strata of sandstone in the Upper Coal Measures occur. There are, in reality, two separate quarries, located at different heights, at the side of a hill west of Steubenville, near the Ohio river. The material from these quarries is used largely for cemetery works, bases of monuments and tombstones, vaults, etc. That from the upper quarry is better adapted to fine work, but it is not so extensively used, because the material is not as accessible as that in the lower quarry. The Episcopal church at Steubenville was constructed of stone from these quarries.

Belmont county is well supplied with material for the ordinary purposes of construction from the sandstones of the Upper Coal Measures and the Lower Barren Measures; and some of the quarries furnish material quite well adapted for ornamental purposes. The most important quarries are those in the eastern part of the county, near Martin's Ferry and near Bellaire. These quarries are located in the hills several hundred feet above the Ohio river. The quarry of Mr. Charles Siebrecht is located about 100 feet above the river in one of these hills. The stratum is a solid mass about 30 feet in thickness. The material is used for general building purposes, principally at Martin's Ferry. The stone-work of the suspension bridge across the Ohio river at Wheeling, West Virginia, is constructed from this material.

The total thickness of the sandstone ledge quarried by Mr. Robinson, near Bellaire, is about 40 feet. The rock, for a depth of 17 feet from the top, is very uniform in texture and general appearance. The portion of the ledge below this is in irregular masses, unfit for building purposes, and is locally called "nigger-head." The layers of stone in the upper 17 feet are quarried for building purposes, and vary in thickness from 4 to 7 feet. This is esteemed as the best material for building purposes found in Belmont county. The arches and abutments of the Baltimore and Ohio Railroad bridge across the Ohio river at Bellaire, and of a number of other bridges on the same railroad, are constructed of this stone. The material finds its principal markets at Bellaire, Ohio, and at Wheeling and Benwood, West Virginia. Traces of coal vegetation are found occasionally between the layers of stone in this quarry. A short distance above this sandstone a vein of coal occurs, and above this a limestone stratum 20 feet in thickness, quarried for furnace flux.

The ledge of rock in Mr. Hutchinson's quarry is about 30 feet in thickness, and is considerably broken into irregular masses. The stone is fine-grained, rather hard, and difficult to cleave in any direction. Near the middle of the ledge are two layers, each about 20 inches in thickness, which are more regular; the rock, however, is found less broken as the excavation advances into the hill. Since this quarry is constantly worked for ballast, it has the advantage of selecting its best material for purposes of construction. However, stone more regular in structure and better adapted to building purposes is quite abundant in this locality. There is also a good flagging stone found here in a different stratum ; but this is quarried only occasionally for temporary demands. The product of the quarry of the Baltimore and Ohio Railroad Company, near Barnsville, is used largely for ballast. It has been used to some extent for purposes of construction on the Baltimore and Ohio railroad. The stratum in which the quarry is located is about 30 feet in thickness, but has only been worked to a depth of 14 feet. The stratum contains few joints and has no divisional planes of stratification. Stone of such fair quality for all ordinary building purposes is so generally distributed throughout this part of the county that it is picked up wherever needed to supply the occasional local demands, and no extensive quarries are developed at any place for the production of building stone.

In Washington county strata of sandstone belonging to the upper series of Coal Measures are quarried for the production of building stone and grindstones in the heavy ledges along the Ohio river hills. The most important quarries are located near Marietta and Constitution. The arrangement of the different sandstone strata, with their alternate shales, coals, and fire-clays, is as follows:

Heavy sand-rock	30 feet.
Blue shale	9 feet.
Heavy sand-rock extensively quarried for grindstones	25 feet.
Sandy shale	20 feet.
Heavy sand-rock quarried in places	36 feet.
Shale, somewhat ferruginous	4 feet.
Coal, Hobson's seam	1 foot to 6 inches.
Fire-clay and shale	4 feet.
Interval to Ohio river	42 feet. (*a*)

The quarries near Marietta and Constitution are all, except Mr. T. B. Townsend's, worked in the grindstone stratum, and produce, besides grindstones, material for all general building purposes. The building stone is used principally at Marietta and at various points along the Ohio river. In different portions of the stratum there are sufficient varieties of texture to furnish all kinds of grits used for wet grinding, and the grindstones are shipped to all manufacturing points in the United States. The rock splits readily in the direction of the stratification. The advantages offered for the transportation of the product by the proximity of the quarries to the Ohio river greatly aid their development.

The quarry of Mr. Townsend is located on the Muskingum river, and is devoted to the production of a material mainly for bridge-building purposes, and some for general purposes of construction. The section exposed in this quarry exhibits 65 feet of sand-rock, which becomes still heavier as the quarry progresses into the hill. It consists of layers from $4\frac{1}{2}$ to 18 feet in thickness. In the lower portion of the quarry the material is rather finer in texture and superior in quality to that in the upper portion. The quarry was opened for the special purpose of obtaining stone for the ice harbor, now in process of construction at Marietta; but it also furnishes material for other structures.

(*a*) Geological Survey of Ohio, Vol. II, p. 472; "Report of Second District," by E. B. Andrews.

LIMESTONE.

By Dr. Geo. W. Hawes.

Cincinnati group.—The southwestern corner of Ohio is covered by what is called the Cincinnati group of limestones, a geological formation equivalent to the Hudson River beds of New York. These rocks were very early quarried and used for construction purposes, although the special quarries that are at present in operation have been much more recently developed. Quarries once located on the outskirts of Cincinnati have suspended operations on account of the growth of the city. The material is mentioned in the early reports upon the geology of Ohio as having been used in 1838 for building, burning into lime, macadamizing roads, and even for ornamental purposes. (*a*)

Professor Orton gives the following as the order in which the beds which constitute the Cincinnati group in southwestern Ohio are arranged :

The Point Pleasant beds, 50 feet thick, constitute the lowest of the series. The Cincinnati beds proper overlie these, and are 425 feet thick. The Lebanon beds are the highest, and are 300 feet thick. Quarries are developed in each of these horizons. The rocks whereever they are quarried are very much alike, and are called in commerce blue limestones. As a rule they are filled with fossils, and occur in layers that are from half an inch to 12 inches in thickness, which are interstratified with beds of shale or clay. Professor Orton says that while this blue limestone has been used from the first settlement of the country, it has hitherto enjoyed the reputation of being serviceable rather than beautiful; but within the last few years it has been so treated by combination with other building stones as to produce very fine architectural effects, as can be seen in the recent buildings of the city and suburbs of Cincinnati. (*b*)

The quarries in the Cincinnati group of limestones are located near Cincinnati, more on account of the local demand for the most accessible stone than for the superior quality of the material at this point. There are limestones in the river bed which are upon the same level as the quarries which produce excellent stone at Covington, upon the

(*a*) Professor Locke in Second Annual Report on Geological Survey of Ohio, by W. W. Mather, 1838.

(*b*) Report of the Geological Survey of Ohio, Vol. I, Part i, p. 378.

opposite shore. These beds are overlaid by 250 feet of shales, which are called by Professor Orton the "Eden shales"; and these in turn are overlaid by the so-called "Hill Quarry" beds of limestones, from which most of the stone used in the county is derived.

Six quarries of importance are at present in operation at Cincinnati with exposures of from 40 to 75 feet, of which some 10 to 25 feet is distributed throughout the section in layers from 1 inch to 10 inches in thickness. Slabs 6 feet long and 6 feet wide can be extracted.

The lime which is burned from the stones of the Cincinnati group is dark and unfit for plastering, but for foundations, etc., it is of especial value, as it possesses some hydraulic capacity. Specifications for cellar walls, bridge abutments, etc., in this region always call for Cincinnati lime.

It is thus seen that the stone is interstratified with beds of shale, which forms from one-fourth to one-third of the whole section. In other parts of the series the proportion of stone falls to one-tenth of the thickness of the section, the main mass being composed of shale or clay. The stone seldom exists in such condition as to make a building stone that can be used in fronts, and it is mainly employed for rough construction, although some of the churches in Cincinnati have been built from it.

As the dip of the blue-limestone beds is mainly to the north, while the direction of the Ohio valley at Cincinnati is toward the south, by proceeding up the river layers of the formation are brought to the surface that are lower than any occurring in the river quarries of the city. The Point Pleasant quarries, in Clermont county, are consequently situated in a different and lower level, and Professor Orton states that this section furnishes the most desirable building stone of the blue-limestone series. It dresses more easily and possesses a better shade of color, combined with a general exemption from the weathered seams that disfigure the higher beds. The quarries are situated at the water's edge, and river transportation enables the stone to be brought to the city easily. In a church on the corner of Eighth and Elm streets, Cincinnati, the appearance of the stone can be seen to the best advantage. As the demand for the stone is local, the annual production fluctuates between wide limits, and the value of the product has sometimes fallen very low. There is quite a large number of small quarries in the neighborhood, each producing from $200 to $300 worth of stone annually.

The quarries in Butler county, from which are extracted the blue-limestone of the Cincinnati group, are situated at and near Hamilton. The character of the stone and the method of its occurrence are the same as those of the other limestone obtained from this group. A quarry at Hamilton exhibits a section 40 feet thick, of which 18 feet is of stone distributed in layers of varying thickness throughout the whole section. The individual layers are from 1 inch to 12 inches in thickness, and the heaviest layers are found at the bottom.

The limestones of the Cincinnati group are all highly fossiliferous, and the number and variety of the forms found in them have given to them a geological celebrity. The quarrying operations are constantly bringing to light rare and interesting species, but the specimens which were collected and sent to the National Museum as typical contain a predominating number of fossils of the species Chaetetes (now Monticulipora), with the shells of brachiopods cemented together by limestone. When polished the stones appear very beautiful on account of the diversity and delicacy of these fossil forms, but owing to the presence of clay in the cementing material the polish is not uniform over the whole surface. This does not detract especially from the value of the stone for ornamental purposes, since the fossil forms which give the stone its beauty by receiving the highest polish are thereby brought into prominence.

The fragments of fossils of which the stone so largely consists were apparently first washed together along with the clayey limestone and mud which forms the cement, and which fills the interiors of the fossil forms. This was apparently solidified into a vesicular rock, and the cavities were subsequently filled with clear crystalline calcite. The process of such formation is frequently seen in the Ohio limestone, some of which are porous, and are filled with cavities which are but partially filled with new crystalline product. Analyses were made of these limestones by Dr. Wormley for the *Report on the Geological Survey of Ohio.* (*a*)

The Point Pleasant rock, which is considered to be the best for building purposes, was by him shown to have the following composition:

	Per cent.
Siliceous matter	12.00
Alumina and iron oxide	7.00
Calcium carbonate	79.30
Magnesium "	0.91
Total	99.21

(*a*) Geology of Ohio, Vol. I, Part i, p. 375.

NIAGARA GROUP.—The rocks of the Niagara period occupy that portion of Preble county in which quarries are extensively developed. The Niagara limestones in Ohio are very often called the Cliff limestones, because they stand in bluffs along the river valleys, and they are more esteemed as building stones than the rocks of the underlying Cincinnati group.

The following sketch by Professor Orton shows the arrangement of the rocks in this county: (*b*)

Upper Silurian, Niagara group	Guelph or Cedarville division. Springfield stone. Niagara shales. Dayton stone. Clinton limestone.
Lower Silurian, Cincinnati group, Lebanon division.	

The approximate thicknesses of the divisions are about as follows:

	Feet.
Niagara group	75
Clinton limestone	15
Cincinnati group	225

Of these stones the blue limestone is quarried in the southern part of the county, and was formerly the main dependence in that region as a source of lime, but the Cliff limestone was brought subsequently into universal use as a substitute.

The Clinton limestone has been largely in demand for chimney-backs, and has been found especially desirable for all those constructions which are exposed to fire or heat. It is an unevenly-bedded stone, often sandy in texture, but no quarries are so extensively developed in it as to merit consideration.

The stone which is quarried near Eaton is the geological equivalent of the building stone of Springfield and Yellow Springs. One of the largest and oldest of the quarries is 3 miles northeast of Eaton; another, 5½ miles northeast of Eaton, is smaller. A section of the first quarry shows 6 feet of so-called cutting stone at the bottom overlaid by 4 feet of a good building stone with 3½ feet of drift material upon the top. A number of grades of material are quarried, and stone suitable for flaggings and copings, as well as for fine and rough constructions, is obtained.

It is stated that a stone 10 by 12 feet in superficial dimensions has been taken out, and that very much larger stones can be obtained. It is principally used for rough building purposes and is sent to Eaton, Ohio, and to Richmond, Indiana, by team and by rail.

(*b*) Geological Survey of Ohio, Vol. III, Part i, p. 409.

These quarries yield an unusually fine quality of flagging stone, the material lying in very even courses of suitable thickness. An analysis of the limestone was made for the Ohio survey by Professor Wormley, (c) and the composition of the stone is shown to be as follows:

Calcium carbonate	49.75
Magnesium	35.87
Alumina and iron oxide	4.40
Siliceous matter	9.40
Total	99.42

The largest quarries in Preble county are located at New Paris. The building-stone courses are here accessible, but the production of burned lime is the chief industry, yielding twelve-nineteenths of the gross earnings; the lime is distributed mainly to the westward by the railroads leading out of Richmond, Indiana. The quarries produce also flaggings, copings, bridge and building stones—in fact, the material for any construction can be here obtained.

Immense blocks are said to have been quarried at this place. The chief market for the stone quarried at New Paris is in eastern Indiana. The specimens sent to the National Museum from Preble county are all of a drab color, compact, and rather earthy in appearance, incapable of taking a high polish, and possessing a characteristic appearance due to the presence of porphyritic crystals of a clear, glassy nature, and which become very prominent upon the smooth or polished surfaces. These glassy crystals are of calcite, and the forms of the fossils which are sometimes seen are filled with the same glassy material. The earthy ground mass, which constitutes the bulk of the rock, will not dissolve in dilute acid, and is of a dolomitic character, as is shown by the analyses that have been cited. The stones consist of irregular, minute grains, which are closely fitted together with rhombohedral crystals of dolomite developed among them. All of the sections when magnified show very numerous but exceedingly small particles of pyrites. This is what probably produced the 4 or 6 inches of sap or discolored rock adjoining the natural clefts.

The limestones quarried at Piqua, Miami county, are from the low-

(c) Report of the Geological Survey of Ohio, Vol. III, Part i, p. 405.

est horizon of the Niagara formation, (a) and are therefore exact equivalents of the Dayton stone. They are immediately underlaid by the Clinton limestones, and the glacial action has plowed away the stones of the Springfield and Covington type which once overlaid them. The material here extracted is of good quality. The stone lands sometimes bring $2,000 per acre near Dayton. Their value is indicated by the circumstance that, although the stone is not more than 16 feet in thickness, it is frequently extracted in places where 20 feet of dirt and drift must be removed from above it. The stone belonging to this horizon is usually very strong, specimens having been found to resist a crushing force of 30 tons on a 2-inch cube. The quarries are situated at and directly south of Piqua, upon the west side of the river, with the exception of one quarry 2½ miles south of the town. The material is sent by rail, canal, and team to the neighboring towns and cities of Ohio and Indiana, where it is used mostly for rough building purposes. No prominent structures have as yet been constructed from it. The thickness of the strata varies, and it is therefore possible to obtain slabs suitable for pavements. Indeed, it is claimed that slabs 20 feet square from some quarries are accessible. The town of Piqua is mostly paved with this stone, utilizing for this purpose the poorer and inferior layers. The walks would be greatly improved by the use of the better layers.

In the quarries immediately at Piqua, about 2½ feet of the lowest layers are heavy and thick, and are used for bridge stones. Then follow about 7 feet of building stone, overlaid in one quarry by 1 foot of well stone and 2 feet of drift, and in the others there are 7 or 8 feet of drift to be removed. Quarries below the town are overlaid by 22 feet of drift, the lower portion of which is composed of fragments of broken limestone, of all sizes and shapes, piled together with an intermixture of gravel. This stone, like the Dayton stone, is mainly composed of calcium carbonate, which, it is said, usually constitutes over 90 per cent. of the whole. That it varies, however, between quite wide limits is shown by the circumstance that of the two specimens sent on, one is quite dolomitic, and will dissolve but little in dilute hydrochloric acid. It contains streaks and clear crystalline spots, which are of calcium carbonate, and under the microscope in minute structure it is found to contain more or less of sharply-defined crystals, which are probably dolomite. The stone in some of its layers contains more or less

(a) Geological Survey of Ohio, Vol. III, Part i, p. 468: "Geology of Miami County," by John Hussey.

pyrites, and is mainly of the variety which is called blue limestone. Some of it will receive a tolerably fair polish, and when thus treated it has a prettily-mottled structure, or a gray and white-banded structure, according as the blocks are polished upon a plane parallel or perpendicular to the stratification.

The Dayton limestone is an evenly-bedded, massive, gray carbonate of lime, which is sparingly charged with fossils, and which is quarried from the very lowermost courses of the Niagara formation. It is found in firm, heavy courses that are at times 10 feet in thickness, though often very much less. So-called cutting stone is obtained from these beds. This term "cutting stone" is generally employed to designate stone which comes out in large blocks suitable for steps, platforms, etc. Cutting stone is sharply distinguished from building stones in all the quarries of western Ohio, and brings several times the price per cubic foot of the latter. The thinner and inferior strata serve a great diversity of uses.

Although stone of excellent quality occurs in various portions of Montgomery and Greene counties, the market has been thus far largely supplied by the quarries situated in the neighborhood of Dayton. Five quarries have there been opened in a belt which lies a mile and a half east of the town, whose sections exhibit 5 feet of the so-called cutting stone, overlaid by from 10 to 18 feet of drift. They produce all kinds of building stone (graded in from three to six grades), which is mainly sent to Dayton and to Cincinnati. The court-house and some of the churches in Dayton were constructed of this stone.

Another quarry in this same horizon, situated 7½ miles north of Dayton, has only 5 feet of drift to be removed; but, on the other hand, the thickness of the stratum of cutting stone is least in this quarry. The court-house at Sidney, Ohio, is built of this stone.

At a quarry operated 6 miles east of Dayton the deposit consists of 4 feet of cutting stone, overlaid by 6 feet of a yellow-colored stone, the whole capped by 9 feet of drift. Two miles farther to the east lies a quarry which contains 4 feet of cutting stone overlaid by 3 feet of drift. The last two quarries are in Greene county.

Quarries have been opened in the same stratum of stone in the neighborhood of Xenia, and these have been widely known and extensively worked. This is in fact one of the three localities to which the contracts for the foundations of large works in Cincinnati were formerly confined, the specifications calling for Xenia, Centerville, or Dayton

stone. This is the easternmost exposure of the last named stone. The Dayton limestone is a peculiar and exceptional member of the great Niagara series in southwestern Ohio. It lies in lenticular masses of comparatively small extent, perhaps not more than two or three square miles occurring in any one area. Throughout Montgomery and Greene counties the shale, which forms the next succeeding layer of the Niagara formation, has in almost all cases been removed by erosion, and thus it happens that the stone is immediately covered with the deposits of bowlders, clay, and dirt, as described. The glaciers which have produced this result have polished and striated the rocks in many cases.

The composition of the Dayton limestone is shown from the following analysis, made by Dr. Locke in 1838: (*a*)

	Per cent.
Calcium carbonate	92.40
Magnesium carbonate	1.10
Iron protoxide	0.53
Insoluble material	1.70
Soluble silica	0.90
Water	1.08
Total	97.71

The stone from the McDonald quarry, near Xenia, has been analyzed by Professor Wormley, (*b*) with the following result:

	Per cent.
Calcium carbonate	84.50
Magnesium carbonate	11.16
Alumina and iron oxide	2.00
Siliceous matter	2.20
Total	99.86

When examined under the microscope these stones, as illustrated by the samples sent, are found to be composed largely of fossil fragments, which are so broken and destroyed as to be unrecognizable to the unaided eye. These fragments are united by an extremely fine-ground mass, in which here and there a sharply-definded rhombohedral form is porphyritically developed. These porphyritic crystals are quite prominent in the stone from the Huffman Stone Company's quarry, near

(*a*) Report of Progress upon the Geological Survey of Ohio, 1869, p. 152.

(*b*) Geological Survey of Ohio, Vol. II. Part i, p. 669.

Dayton. A section of this stone was treated with dilute acid, when everything dissolved with the greatest facility, with the exception of these porphyritic crystals, which may consequently be supposed to be rhombohedrons of dolomite which have developed themselves in the mass of calcite. Although stones of such excellent quality are obtained from the Dayton beds, it is necessary to mention that stones occur in which pyrites exist in large crystals at least half an inch square. Pyrites is recognizable in the thin section of all specimens sent to us, though this ingredient is not so disastrous in a stone of this nature as it is in other more porous stones, in which the pyrites would not merely be reached much quicker by the decomposing agencies, but in which the products of decomposition would more quickly find their way through the cracks and crevices of the stone. The material has attained a high reputation. It has been more or less used at various points, as Chicago, Louisville, Columbus and Toledo. Cincinnati has used it largely, but for the last 15 or 20 years it has not been shipped so extensively to these points.

Beds of the Dayton limestone are developed in Clinton county. They have been quarried at Wilmington and Centerville, but the old quarries which have been reported as in active operation during the census year are situated 1¼ miles southwestward from Lumberton. The quarry consists of 5 feet of stone, which is mostly used for rough building purposes, and is overlaid by 2 feet of drift. The material is hard, very compact, and capable even of assuming a quite high polish. It is also very noticeable that the rock, which to the unaided eye appears so compact and non-fossiliferous, really contains a very great number of fossil fragments. It also contains some pyrites, distributed through the mass in the form of very sharply defined cubical crystals, which in the specimens sent are entirely invisble to the unaided eye, and which cannot be called deleterious. There are yellowish spots and streaks in some of the layers, but this appears to result from the inclusion of clayey material rather than from the oxidation of the iron sulphide. The stone from this quarry finds its market principally in Clinton and Fayette counties.

The rocks in Clarke county (*c*) are like those found in Montgomery and Greene counties, but the important quarrying operations are all carried on in the upper beds of the Niagara formation, which are typi-

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(*c*) Geological Survey of Ohio, Vol. I, Part i, p. 450: Geology of Clarke County, by Edward Orton.

cally developed at and about Springfield. These beds are of particular value, as they possess a greater thickness than any one of the underlying formations in the county, and cover a much wider area. In the same quarries building stones of excellent quality are combined with material that is converted into peculiarly excellent lime. The accompanying section of the rocks at Springfield indicates the relationship of the beds.

The underlying shale occupies the position of the limestone which is quarried so extensively at Dayton and at Piqua. The overlying beds of building stone have given the name to the so-called Springfield division of the Niagara, and the less compact layers of the overlying so-called Guelph formation are broken up and burned.

The Springfield building stone is a carbonate of lime and magnesia, containing only small percentages of silica and alumina. Its usual color is a light drab, although blue and yellow courses occur. The light-colored stone sometimes is defaced by faint reddish streaks which are caused by the presence of iron oxide, and which render the stone unfit for some of the finer uses. The thickness of this deposit of building stone is not more than 20 feet, and is usually less. The lowest courses are blue in color, and although massive in appearance, they sometimes prove treacherous as building stones, for they are liable to lose their dressing surfaces, while their seams widen and they undergo a slow disintegration. The walls of the jail in Springfield furnish an illustration of these characteristics. The drab courses are almost all of durable building stone, and furnish an invaluable supply of building material for Springfield and the adjacent country.

The difference between the blue and the yellow courses in most of the limestones of Ohio appears to depend upon whether the iron exists as pyrites or as oxide of iron. The pyrites existing in a fine state of subdivision appears black even under the microscope, and the blue color of the stones apparently disappears with the oxidation of the pyrites. This furnishes an illustration of the circumstance that stones are often improved by decompositions which take place inside the beds, for if their value is not thereby destroyed there is much less danger of a disintegration by a decomposition of the quarried stones.

From quarries within 1½ miles west of Springfield the material for the culverts in the state road were obtained, and the material for the bridge at Marysville and for the Masonic hall at Urbana. These quar-

ries are known as the old state quarries, because the material was used in many constructions on the National road. The quarries are large, but the stone from them is used chiefly in building cellar walls, foundations, and other rough work of a similar nature.

Two miles west of Springfield are situated four quarries which furnish similar stone, that is used in Springfield, Dayton, Urbana, London, and Marysville. In all of them the cap-rocks are burned into lime, and the larger portion of the profits results from its sale.

In all cases it is the overlying Guelph beds which are burned, as the courses of building stones contain a considerable percentage of silica and alumina, and cannot be converted into good lime, although some of this material makes a fair cement. The lime product of these quarries finds its way in small quantities as far as New Orleans. It is mild, cool, and strong, and also very white. There is no trouble in laying seven bricks with one spreading of mortar, and skillful workmen can lay twelve bricks with one spreading. The superior quality of this lime is worthy of note, since it is ordinarily considered that the value of lime is diminished by the presence of magnesia.

The composition of the Springfield limestones is shown by the following analyses of the middle and upper beds in Mr. Frey's quarries near Springfield. These analyses were made by Professor Wormley for the *Report on the Geological Survey of Ohio:* (a)

	Middle bed.	Upper bed.
Calcium carbonate	54.70	54.70
Magnesium carbonate	44.93	42.37
Alumina and iron sesquioxide	0.20	1.00
Siliceous matter	0.10	1.50
Total	99.93	99.57

It is thus seen that the rocks are very nearly typical dolomites. They vary somewhat in composition, but not so as to at all influence their value as building stones. They possess an open and porous structure, and are incapable of assuming a polish or being used for ornamental purposes. In their microscopic structure they are seen to be of the crystalline granular type, the fossiliferous character being obliterated from the microscopic structure, although fossils are not rare in the rock.

The Yellow Springs quarries produce a magnesian limestone which

(a) Geological Survey of Ohio, Vol. I, Part i, p. 474.

is very easily worked, and the larger part of which is durable. These quarries are upon the same horizon as the Springfield quarries, and produce stone of the same nature. The courses vary in thickness from 4 to 14 inches, and some of them answer very well for cutting stone. The same qualified commendation can be given to them for flagging, but the quarries have not been extensively developed with the end in view of producing this material. For general masonry the stone has proved very serviceable, and for economy is not surpassed by any stone in the state. There are two colors, which are obtained from different courses, and which are denominated as blue and drab; the blue courses weather to drab in exposed places, but it is not certain that all of the drab beds have been made by oxidation of blue layers. The blue beds sometimes prove treacherous, and even the firm and massive appearance of the stone furnishes no safe guide in judging of its power to withstand the atmosphere. By far the larger portion, however, is excellent in this respect, and the drab courses are almost without exception satisfactory.

Three-quarters of the gross earnings of these quarries are, on an average, obtained from the sale of lime, sent to market under the name of the Springfield lime, which is the standard for southwestern Ohio.

A section of the quarry shows at the bottom some layers of building and cutting stone, above which is a 10-foot bed of solid limestone containing the well-known fossils *Pentamerus oblongus*, and above are 18 feet of the "shelly" limestone, which is burned. The principal quarry at this place produces stone for bridges, steps, and sills, which are principally used in the vicinity of Yellow Springs. The composition of the stone from this quarry is indicated by the following analysis by Professor Wormley: (*a*)

	Per cent.
Calcium carbonate	51.10
Magnesium carbonate	41.12
Sand and silica	5.40
Alumina, with a trace of iron oxide	1.40
Total	99.02

Several quarries in Miami county resemble those at Springfield, and are located in the same geological stratum. They are rendered valuable

(*a*) Report of the Geological Survey of Ohio, Vol. II, Part i, p. 672.

by the circumstance that for 50 miles in some directions there is no other developed quarry. To the northeast, north, and northwest the region is heavily buried under beds of drift, and consequently building stones are inaccessible. The material from the Covington quarries is distributed, therefore, very widely. The stripping is light, the drainage easy, the quantity and quality of the stone are both excellent; and great variety exists in the thickness of the various strata.

The Covington stone is chiefly used for building and bridge construction, and it is mostly consumed in Covington, Ohio, and Winchester and Marion, Indiana. Some bridges on the Pan-Handle railroad have been constructed from this material. At the town of Covington there are six quarries in active operation, as indicated by the table. Some of these must soon be given up, for they lie within the city limits, and houses are being now constructed in their immediate neighborhood.

The material resembles that which is quarried at Springfield in being porous and easily cut. Of the specimens sent to the museum one was blue and one yellow, and upon examination it was found that they differed not merely in the circumstance already mentioned, in that the blue layers contain unoxidized pyrites and the other hydrous iron oxide, but the blue specimen was a dolomite which would not effervesce in acids, while the yellow specimen was much more calcareous. In microscopic properties this stone presents no peculiarities. It belongs to what we have designated as the porphyritic type; that is, it contains rhombohedral crystals of dolomite developed in a mass of formless grains of calcite.

In Shelby county the upper portion of the Niagara formation is developed, and several quarries have been opened, the products of which are almost entirely burned into lime. Building stones can be there obtained at any time and in any quantity desired.

Hancock county is occupied by rocks of the Niagara and Helderberg periods, and although the Niagara rocks which from here extend in a narrow strip northward to lake Erie appear to be separated from that great area of Niagara rocks in which the Springfield and Dayton quarries are situated; they probably extend beneath the Helderberg rocks that intervene and form a portion of the same deposit. The rocks quarried at Findlay possess characters almost identical with those of the Springfield stones. They possess a rather porous and open structure, are drab in color, and occur in courses from 3 to 12 inches in thickness. The

stone is strong and durable, and none of it has as yet shown any bad effects from exposure to moisture or frost. It is rather hard to dress, and stone-workers call it "plucky." The horizontal surfaces are generally roughened by small angular prominences which fit into corresponding depressions in the superimposed layer, forming the structure which is known as "suture" jointings. The dip here is very slight, and the top course in all of the Findlay quarries is evenly bedded and about 1 foot thick. The "seams" (open joints) are from 25 to 100 feet apart, and the close joints usually run at right angles to these seams at greater or less intervals. For this reason, if the quarry is stripped over a sufficient space, the rock can be obtained without blasting. The material from these quarries is used for the foundations of buildings and for bridge abutments in the county, and last year some was shipped to Seneca and Allen counties.

In composition the stone from the Findlay quarries is dolomitic and possesses the characters of the upper Niagara beds. In microscopic structure it is beautifully crystalline, the whole mass of the rock being made up of an aggregate of more or less well-defined rhombohedral crystals.

It appears that blocks much larger than can possibly be required are obtainable here, and that the material, although at present used only for rough construction, could be safely applied as a building stone. Although the present quarries have been opened quite recently, along the same streams upon which these are situated and within a short distance of them, quarries have been in operation for more than twenty years.

Lower Helderberg.—The Lower Helderberg formation is exposed in a narrow strip (*a*) upon the boundaries of Highland and Ross counties, and indeed more stone is taken from the quarries at Greenfield than from any others in the Helderberg formation of Ohio. The stone is regular in its bedding, and, therefore, curbings and crossings of excellent quality are easily extracted. In the Cincinnati market it is largely employed for these purposes. Slabs 3 or 4 inches thick, with a superficial area of 4 feet, can be obtained with surfaces as smooth and regular as if sawed. These stones can be used for door-steps and like purposes without any dressing. The courses are never heavy, seldom exceeding 14 inches, and usually ranging between 4 and 8 inches in thickness.

(*a*) Geological Survey of Ohio, Report of Progress in 1870, p. 255: "Geology of Highland County," by Professor Edward Orton.

The stone is exceedingly strong, 2-inch cubes having been found to stand a pressure of over 50,000 pounds. The quarries produce no waste material, as their spalls are saved to be burned into lime of fair quality. Perpetual kilns are set upon the edge of the Greenfield quarries, the floors of which are kept clean and free from accumulations of refuse of any kind, and the lime produced is similar to that obtained from the Niagara formations, but it possessess in some degree hydraulic properties which make it especially adaptable for outside work.

The stone produced is drab in color when first raised, but upon exposure it generally acquires a yellowish-brown shade. It is ordinarily used only for the rougher purposes of construction and for flaggings and curbings, but, by proper selection and skillful dressing, stone can be obtained from the quarries that produce a good architectural effect. Without such an exercise of taste and judgment, the stone does not appear well, owing to its monotonous gray color, which contrasts unpleasantly with the white lines of mortar. On the other hand, its regular bedding renders it peculiarly suitable for ordinary purposes, as it can be laid upon its even bed surfaces easily, and therefore can be worked with facility and economy. The stone finds its principal market in Cincinnati.

It will be noticed that of the large quarries which supply the Cincinnati market but one is in Highland county. The other is situated in the town of Greenfield, in Ross county. In the Highland County quarry one-twentieth of the profit results from the sale of lime, but in the Ross County quarry more than one-half is burned.

In the Ross County quarry the section shows 42 feet of stone disposed in layers, all of which are available. The quarry is capped by 10 feet of drift material, which constitutes all of the stripping. The Highland County quarry shows 35 feet of stone of a like character overlaid by 6 feet of drift.

The stone in the main is non-fossiliferous, but upon the surfaces of a few layers there are found the forms of the *Leperditia alta,* which is a characteristic fossil of the Helderberg formation. A layer of concretions from 1 inch to 3 inches in diameter is found in the upper part of the section, and short cylindrical columns which fall out, leaving cylindrical cavities in the stone 3 or 4 inches in diameter, occur in considerable numbers, and which are supposed to be due to the effects of pressure.

Nodules of zinc-blende are not uncommon in the Greenfield stone,

and the fossil corals are sometimes composed of silica, which also is distributed through some of the stone in bands that separate the layers.

In composition the stone is nearly a typical dolomite, as is indicated by the following analysis: (*b*)

	Per cent.
Calcium carbonate	53.67
Magnesium carbonate	42.42
Alumina and iron	1.30
Calcium and magnesium silicates	1.44
Silica	1.00
Total	99.83

When examined under the microscope the whole stone shows the characteristic crystalline granular structure of the Helderberg formation. There are streaks of iron oxide and carbonaceous matter which proceed in regular wavy lines through the sections, and these bituminous substances are what give to the stone the strong fetid odor which is produced by striking or cutting it. The quality of the lime produced is another evidence that magnesian limestones may be converted into lime of excellent quality.

Quarry operations have been carried on at Greenfield since the first settlement of the country, to satisfy the local demand, but in recent times the business has been greatly enlarged for the more distant markets along the line of railroads, and especially for the Cincinnati demand. The supply of stone is practically inexhaustible.

In the southern and western part of Champaign county the Helderberg or Water-lime rocks have been quarried in numerous places; formerly a quarry at Salem supplied most of the local demand, and the building and flagging stones used in Urbana were obtained there until the sandstone of Berea superseded them. The stone obtained in the neighborhood of Urbana is of indifferent quality for building purposes, but here it is found in a drift-covered region in an area which for 25 or 30 miles in each direction is devoid of stone. Only about 14 feet of the upper strata have been much quarried. The floor has been sunk to a greater depth, and the stone from the lower courses is proving itself to be a valuable building stone for rougher work. There is no so-called cutting

(*b*) Report of Progress of Geological Survey of Ohio, 1870, p. 287.

stone in the quarry, and the accompanying section will give an idea of the method in which the strata of the Helderberg are arranged at this point. It will be noticed that there is much greater diversity as regards stratification than is shown in the Greenfield quarries.

The specimen sent to the National Museum is a light drab stone, somewhat streaked with red. Its material is of the same character as that of the other Helderberg stones—that is, a dolomite with a fine, crystaline, microscopic structure, and which emits a bituminous odor when struck with a hammer, although the odor is not so strong as in the case of some other Helderberg rocks.

Allen county is almost entirely covered by limestones of the Water-lime or Helderberg formation, (*a*) and all of the quarries that have been considered worthy of note extract stone from these beds that is used for the more ordinary building purposes and for foundations and under-pinnings. The upper beds of the Niagara formation occur in the south-eastern corner of the county, and a few quarries were once opened in those rocks, but the building material that was extracted was inferior, and the production of quicklime from them was not profitable.

Although the building stone obtained from the Helderberg is, as a rule, not of excellent quality, still, as it is the only accessible material, it is of much value.

The stone quarried directly in Lima is an inferior building stone, and is seldom used for foundations above ground, but is in demand for the underground portions of foundations. The quarry is worked more to obtain stone for macadamizing than for any other purpose. It occurs in thin layers, and a block 6 inches thick is seldom obtained. This thinly-bedded character renders it applicable as a flagging stone ; the bedding, however, is uneven.

The material obtained from this quarry is a dark gray dolomite, which is quite porous in its character ; it dissolves in hot acid with very little residue, and the solution is found to contain only traces of iron oxide, which the microscope proves to exist in the state of pyrites. The polishing of a face upon this stone renders its fossiliferous character very prominent, which is not common in the rocks of this formation. The stone is very bituminous and gives forth a fetid odor when struck with the hammer.

(*a*) Geological Survey of Ohio, Vol. II, Part i, p. 397: Report on the "Geology of Allen County,"

A quarry 4 miles north of Lima is said to produce some material of much better quality. It is situated near the Dayton and Michigan railroad, but a side track could not be constructed to it without considerable expense on account of the heavy grading that would be necessary. Some of the courses are over 1 foot thick, and some from 4 to 6 inches thick have been used for sidewalk paving in front of the Lima Machine Works, where it gives indication of both strength and durability. The following is a section of the strata in the quarry :

	Feet.
Soil	3
Building stone for ordinary foundations	3
Dark gray paving stone	1½
Blue shaly material	...
Blue stone	...

There is no natural drainage below the paving stone, and for this reason the underlying blue-stone has not been extensively quarried. According to the testimony of all builders and contractors the stone in the bottom of this quarry is the best building material found within a radius of at least 30 miles. The shaly rock which overlies the blue-stone forms good material for the macadamizing of roads. The material above the paving stone, which is used for foundations, occurs in thin beds which are never more than 3 inches in thickness.

The specimen which was sent from this quarry was taken from the lower or "blue-stone" layers ; it has a dark-gray color, finely banded with yet darker lines, and much more compact than most of the stones sent from the quarries in the Helderberg. Indeed, no pores or cavities were found in it, and its texture was such that it admitted of a fair polish, as indeed do most of the Helderberg limestones. The stone from this quarry is a dolomite, but on being dissolved in hot acid quite a large residue of argillaceous character is left undissolved, and it contains bituminous substances which impart to it the character of a fetid limestone. It contains little or no iron.

A quarry is situated 5½ miles northeast of Lima, and the following section indicates its character and the uses to which the stone is applied :

Stripping	feet...	5
Road stone	do.....	3
Gray building stones	do.....	3
Two courses of blue-stone	inches...	6
Blue Clay	do.....	½
Gray building stone	do.....	...

As in the case of the preceding quarry, the thickness of the stratum of the gray building stone is as yet undetermined. It occurs in courses from 3 to 6 inches thick. The upper 3 feet of stone, which is used for the purpose of macadamizing, is extracted with neither profit nor loss. The material is a more or less porous dolomite of a gray color, mottled and streaked with black, which is due to the arrangement of the bituminous substances contained in the stone. Of the two specimens sent to the National Museum, one was polished upon a surface parallel with the stratification, and this treatment developed a beautiful structure, due to the presence of a fossil bryozoan, which filled the layer that was cut. Thus the presence of a fossil in abundance was demonstrated, although the rough stone gave no indication of a fossiliferous character. This stone and the one previously described from Lima are the only stones of a fossiliferous character which were sent to the Museum, and which were obtained from the Helderberg formation.

These stones are thus most markedly contrasted with those from the Niagara, which are almost all fossiliferous, as is indicated by microscopic examination, which very often renders the forms evident when they are invisible to the naked eye.

In the eastern part of the township of Bluffton the quarries are better adapted to supplying flagging than building stone, since the thickness of the strata usually varies from 1 inch to 3 inches. When properly laid down these slabs make a very durable paving material for sidewalks, cellar bottoms, etc. They are very hard, but break quite easily into any required shape. The stone is dark-colored and of the same character as those previously described. Its color is imparted to it by bituminous substances, and the dark streaks with which it is filled are very irregular, so that a pattern not at all unattractive to the eye is developed upon the smooth or polished surfaces of the blocks, and when dressed in the usual way and laid with white mortar they make a beautiful wall for smaller buildings. Such large blocks have been moved as to insure the possibility of obtaining blocks as large as might be desired.

Although the quarries described have been recently opened, the stone has been quarried in the immediate neighborhood for fifteen years.

Scott's Crossing is situated 4 miles east of Delphos, on the Pittsburgh, Fort Wayne, and Chicago railroad. A quarry at this place produced a drab-colored limestone, which occurs in courses from 3 to 11 inches thick, and which serves very well for foundations. Samples

which have been in walls for over fifty years show no signs of decay. The quarry is situated in the bed of the Auglaize river, and is not worked early in the spring nor late in the fall, when the water is high. A slight dam is built about the quarry, which is washed out every winter, and in addition heavy rains in the summer frequently destroy the works. No more permanent dam is built, since the site of the quarry is often changed, and no excavation has been made in the vicinity to exceed 6 feet in depth. The material is mostly used in the vicinity for bridge abutments and at Delphos for foundations for buildings. It has been sent, to a limited extent, into Mercer county, over the Toledo, Delphos, and Birmingham railroad, to localities where the Piqua stone is not so readily sent. Ten inches of coarse sand, gravel, and other river deposits cover the stone, and about 18 inches of the cap-rock is used upon the public highways. This is one of the best building stones quarried in Allen county for the purposes to which it is applied.

Van Wert county is covered in its northwestern part by the Niagara beds. The Helderberg limestone underlies the rest of the county, but only few exposures of the rock of either kind are known, as the whole region is mostly covered by drift. (*a*) The county is entirely agricultural, and the stones where quarried furnish materials that are used only for foundations in that neighborhood or burned for lime. The lime-kilns at Straughn have caused the most extensive quarrying operations, and the Helderberg stones there extracted are said to burn easily and cheaply to a beautiful white lime. The Van Wert quarry, which is the only one reported as producing any considerable amount of building material, also produces quicklime; and during the last census year the value of the lime produced was about equal to that of the building stone. The Van Wert stone is a light gray dolomite, which is found in courses from 3 to 7 inches thick. The material thus far has given evidence of being a good building stone. Openings have been made in the limestone at several other points in the county; for example, on the Little Auglaize, in the northeastern part of the county, a stone very much like the Bluffton limestone has been quarried to a small extent for the Delphos market. In the northwestern part of the county some building stone is said to have been obtained in much thicker courses than in any other part.

A very light gray limestone has been quarried at Charloe, on the

(*a*) Report of the Geological Survey of Ohio, Vol. II, Part I, p. 314: "Geology of Van Wert County," by N. H. Winchell.

Auglaize river, in Paulding county, which belongs to the Corniferous formation. This Paulding limestone is a soft stone which occurs in courses about 3 feet thick. It has been sawed, and was used in the foundation of the court-house and also in that of the Russel House at Defiance, where it has suffered from the action of moisture and frost. As other specimens of the same stone do not show this disintegration, its defective character is very likely due to the circumstance that it was quarried too late in the season. A blue limestone is also quarried about 5 miles farther down the river from Charloe, which occurs in courses from 6 to 18 inches thick, and has been used for the construction of locks on the Miami and Erie canal. It is not durable when exposed to atmospheric action, and the quarries have been abandoned. The demand for the material has been destroyed by the introduction of the White House stone from the north and the Piqua stone from the south.

Tiffin is situated exactly upon the boundary between the Niagara and the Helderberg rocks, in Seneca county, and its quarries, although producing only Helderberg rocks, show at some times, at their bases, exposures of the underlying Niagara limestones. These quarries are located on the eastern side of the ridge known as the Cincinnati axis, and the characteristics of the rocks are much the same as those in the quarries on the western side of the anticlinal in the Helderberg formation; but the stones at Tiffin are more massive, and are therefore more suitable for heavy construction. The courses are often 26 inches in thickness, and the stones produced are used largely for foundations and bridge work. The product of quicklime from these quarries is also large.

The stone is light drab in color; it is bituminous, and gives forth a strong odor when hammered, but this characteristic is not so marked as in the dark-colored varieties. The principal market for all three of the quarries situated in Tiffin is furnished by the immediate neighborhood. Beside the quarries in the table there are several smaller ones which are worked in the vicinity of the town, and which produce the same kind of material in less amount.

A short distance west of Fremont several quarries have been opened in the strata of the Water-lime or Helderberg formation.

The only quarry at this point of sufficient importance on account of its production of building stone is situated one mile to the west of Fremont, and in this the value of the lime which was produced from the quarry during the census year was ten times that of the building stone.

The strata suitable for building purposes are from 1 foot to 10 feet in thickness, and the material which does not make an excellent quicklime is comparatively small. As a building stone the material is superior to much of that used in counties to the southwest, although not equal to the Sandusky and Marblehead limestones. It is of a light drab color, full of small cavities, and works very easily, and some of it is soft and pure enough to be sawed. The stripping is sold for macadamizing. It presents the usual microscopic characteristics of the Helderberg rocks, and it dissolves in hot acid, leaving a very slight residue. The qualitative analysis indicates that it is composed of remarkably pure dolomite.

CORNIFEROUS.—Quite a variety of stone is found in the neighborhood of Columbus, for although Franklin county is flat it has a number of geological formations within its limits. To the east lie the Waverly sandstones and the Huron shale, but the limestones of the Corniferous, which lie to the west of Columbus, are by far the most important from an economic stand-point. Thick and heavy layers of stone exist among the strata. From the different layers material suitable for the most diverse uses can be obtained, good quicklime can be made, and being in part a very pure carbonate of lime, the stone is desirable as a flux for smelting iron ores. Of late it has been very extensively applied to the latter purpose, especially in the Hocking Valley region. The quarries are all situated a few miles to the west of Columbus, and have been operated for a long time. Some which have been the most important, for instance the state quarries, from which the material for the state-house and for walls of the state-prison was extracted, are no longer worked, but all of the quarries mentioned in the census tables are immediately about the old quarries and extract the same material. While the state-house was in process of construction, and stone of the best quality was in demand, the Corniferous limestone was worked to a greater depth than it is at present, for the finest quality of stone is found in the lower layers. At present the production of building stone is subordinate to the production of lime and flux.

The Columbus limestone is dense, compact, and strong. There are 12 feet of the upper courses in the present quarries that average 93 per cent. of carbonate of lime, and frequently the percentage rises to 95 or 96, while, on the other hand, there are localities where the Corniferous limestone becomes nearly a typical dolomite, as at Bellefontaine. The stone is fossiliferous, but the fossils are very firmly cemented and do

not appear to weather out; in some cases, indeed, the fossil appears to be firmer than its surrounding stone. In microscopic structure the stone bears the appearance of a fragmental stone, being composed almost entirely of fragments of fossils. In the finer ground mass very perfect little rhombohedrons of dolomite are developed, which in number are apparently disproportionate to the amount of magnesia contained in the stone. Many of the fossils have apparently retained their primitive condition, but others have been dissolved away and the forms filled with crystalline calcite; and this will perhaps explain the different behavior of the fossils in weathering. The stone is somewhat bituminous in character, as evinced by the odor emitted when struck. Its gray color is pleasing to the eye; it works easily, and will even assume a good polish.

Dynamite is used as an explosive to a large extent, any desired number of charges being exploded simultaneously by means of electricity.

Although the common stone for foundations and underpinnings used in Columbus is obtained from the quarries, still, during the census year, no great amount of building stone was extracted, and no important structures were built from the material. The quarries can at any time be operated much more extensively, and will produce a superior quality of stone for fine construction.

In the eastern half of Logan county a large island of Corniferous limestone occurs, the center of which is covered with shales, but all around the edges small quarries have been opened for the purpose of obtaining stone both for building purposes and for lime. (*a*)

At the present time the only quarries of special importance that are located in this district are those which are situated a short distance to the northwest of Bellefontaine, and the material which they produce is used chiefly for rough work. Although capable of producing excellent building material, the more important stone structures in the neighborhood have been built of materials brought from a greater distance. The quarry operations are carried on in a quite primitive manner, and at present the lower strata in one quarry are inaccessible, since no means of drainage have been supplied, and the quarry is filled with water to a depth of from 12 to 15 feet. The top layers of the stone are being extracted, although the lower layers are best suited for purposes of construction.

(*a*) Report of the Geological Survey of Ohio, Vol. III, Part i, p. 482: "Geology of Logan County," by Franklin C. Hill.

The quarry of Angel, Miller & Co., situated a half mile west of Bellefontaine, exhibits the following section:

Drift	feet..	5
Cellar stone	do....	10
Heavy hard stone	do....	5
Honey-combed porous stone	inches..	9
Heavy soft stone	feet..	5

Occasionally some lime is burned at this quarry, although its amount is small and its quality inferior.

The material that is at present produced by these quarries is a typical dolomite, and in microscopic structure consists of a perfect mass of sharply defined large rhombohedral crystals of dolomite cemented together by a mass of minute little crystals of the same form and composition. In many places the crystals are only attached at their corners, leaving angular interspaces, and this accounts for the avidity with which water is absorbed by this stone. The fossiliferous character, if any originally existed, has been entirely obliterated. In color it is light gray, and it works easily and safely. Its microscopic structure is illustrated upon the plate at the end of the chapter.

The first quarry in Marion county was opened in 1825 in what is known as the Marion limestone. Ten acres only are considered as belonging to the quarry. It is situated in the southeastern part of the town of Marion, and is the farthest south of any quarry in the neighborhood producing good building stone. A gray stone occurs about 12 or 14 feet below the surface, and is probably underlaid by blue-stone, but as the gray is considered the best the lower courses have not been opened.

Other quarries are located in the northeastern part of the town which extract material for building and quicklime. The largest quarries are, however, operated on the Columbus and Toledo railroad, one mile north of Marion. The stone is considered very strong and durable. The average thickness of the rocks extracted is not more than 8 inches, although blocks 12 and even 15 inches thick are sometimes obtained. There is no difficulty in extracting blocks of any required dimensions in the bed for all ordinary purposes of construction. The stone is easily quarried, being lifted with bars and broken with sledges, no blasting operations being necessary except to make an opening in the floor of the quarry for deeper workings.

The material is chiefly used for foundations and bridge work, and was largely employed in the construction of the depots and shops of the Columbus and Hocking Valley railroad. It is commonly called blue limestone, although the colors differ at different horizons, and the layers also vary in texture and hardness, each layer, however, being homogeneous. The stone is usually quite fine in grain and rather hard. The following may be regarded as a typical section representing this and all other quarries in the neighborhood of Marion:

	Feet.
Soil	1 to 4
Weathered rock	1 to 4
Blue-stone	1 to 6
Gray-stone	4
Blue-stone	

The overlying blue-stone is found in blocks from the exterior of which a gray color penetrates to a variable depth from the natural joints. It is liable to contain flinty nodules, from which the underlying gray-stone is almost entirely free. The blue-stone in the bottom of the quarry is free from this gray covering; but the intermediate stone, which is all gray, is considered the best material.

In these quarries the gray-stone is found near the top, but in the other quarries reported from this township, being about $1\frac{1}{2}$ miles to the southeast of these, and in the direction of the dip of the strata, this gray layer is not struck until a depth of from 12 to 16 feet from the surface is obtained. A very large amount of the cap-rock has been used for macadamizing streets and for ballast on the Columbus and Toledo railroad. The quarries in this township furnish the greater part of the stone used in the northern part of Union county and in quite a large portion of Hardin county.

The material quarried at Marion is dolomite, containing some calcite. When microscopically examined it is found to consist of a multitude of perfect little rhombohedral crystals, each one of which contains a little black bituminous substance accumulated in its center, and all are cemented together by the calcite, which, although crystalline, does not assume a definite outline. The rock, when treated with cold and dilute acid, effervesces for a while, and the residue when examined is found to consist of a multitude of perfect and beautiful little rhombohedrons. The Marion stone has been selected for representation in the plate of

microscopic sections, and some further remarks concerning its chemical composition and structure will be found in the general remarks that close this chapter.

At Owen's station, in the southern part of the county, there is a quarry in the Corniferous limestone from which over 9,000 tons of lime and broken stone were shipped during the census year. Almost the entire output was used as furnace flux in the Hocking Valley.

Six miles northeast of Marion, in the township of Grand Rapids, the same limestone is worked quite extensively. A ridge occurs at this point in which a number of quarries are located.

Crawford county is well supplied with building material. The limestones are quite well adapted for construction of foundations, but they are not at the present time extensively quarried owing to a number of causes. There are no great demands for stone in this agricultural region, and the home resources are thrown into competition with the Berea grit, which is quite extensively quarried at Leesville, in the southeastern part of the county. In Holmes township, about 6 miles northwest of Bucyrus, and near the Ohio Central railroad, three quarries are at present worked in the Corniferous limestone. The material has much the appearance of the Marion limestone, but, while it may be of the same quality, the courses are generally thinner and not so well bedded.

In Lykins township the same limestone is also quarried to some extent. The material from all these quarries has been used for bridge building and for foundations, but it is more and more displaced by the Leesville sandstone, especially for bridge-building purposes.

A large quantity of quicklime has been produced here which has been shipped from Nevada, in Wyandot county, by the Pittsburgh, Fort Wayne and Chicago railroad.

For building purposes the limestone which is quarried from the Corniferous formation at Bloomville, Seneca county, has a higher reputation than the Helderberg limestones, and indeed it is said that these quarries produce one of the best limestones in northwestern Ohio. The material has been quite extensively used in Tiffin for many years for trimmings and stone fronts, and also for general building purposes in Mansfield and in the surrounding country. Good material for flagging, bridges, and foundations is quarried, and a slab 25 feet square might be obtained. It has already displaced in a measure at Mansfield the sandstones which are quarried in that vicinity.

The specimens sent to the museum are of an attractive gray color and are highly fossiliferous. Some fossils have apparently been entirely removed at some period and their places subsequently supplied with a clear crystalline calcite, and some of the fossil forms are therefore strikingly apparent upon polishing the surface of the stone.

Under the microscope the stone is found to consist of a grand aggregate of fossil fragments, among which here and there the rhombohedral crystals of dolomite are developed in much perfection. The number of these rhombohedral crystals is, as usual, proportionate to the amount of magnesia in the rock, which in this case is about 16 per cent.

The limestone industry in and about Sandusky is one of the most extensive in the state. This is partly due to the abundant and excellent supply of building stone furnished by the Corniferous strata of this region, and partly to the facilities for transportation by water and by rail. The city of Sandusky is founded upon a ledge of limestone, and excavation of any kind necessitates quarrying operations. In early days the stone thus extracted was the cheapest building material accessible, and came to be used very extensively. As a result the use of stone is more general there than in any other Ohio town.

At Sandusky the upper layers of the Corniferous formation are composed of a blue limestone of a thickness from 20 to 25 feet. This is underlaid by the white Sandusky limestone, which is found in thicker courses, cuts easier, and is capable of making a better lime; but at Sandusky this stratum, which is also from 20 to 25 feet in thickness, lies beneath the level of the lake, and is not readily accessible. The dip of the strata is, however, away from the water, and consequently this layer of white limestone is brought to the surface at Marblehead and on Kelley's island.

The largest quarries are situated at these points. Sandusky itself, owing to the circumstances mentioned, possesses quite a large number of quarries, and the city itself constitutes in fact a great limestone quarry covered with but a very shallow layer of soil or earth. These city quarries have been worked very largely for home and foreign supply, not less than 12 acres having been excavated to a depth of 8 feet. The Sandusky blue limestone is found in layers of convenient thickness, and the range work furnished by it presents an attractive appearance. The courses vary between 4 and 10 inches in thickness, and the material is used largely for flaggings, although not very well adapted for this purpose. is laid in slabs from 4 to 8 feet square, which are not very smooth or

regular until they become polished by wear, and then they are dangerously smooth. For construction purposes the stone has proven very durable, and the best foundations can be secured at small expense if made from this stone. It is also used for macadamizing the streets, and recently it has been found that a foundation of the Sandusky blue limestone can be advantageously overlaid by a thin coat of the white limestone which binds and cements the road-bed.

All of the quarries which in the tables are indicated as existing in the corporate limits of Sandusky are essentially one, as they produce the same material, and only in a single case has a quarry been sunk to the level of the underlying white limestone. About one hundred and eighty houses in the city have been constructed of this stone. The specimens sent to the National Museum from various quarries are identical in their minutest structures. They are bluish-gray in color, compact, and present a fine appearance, however dressed. Although they effervesce rapidly in acid, they are quite magnesian, and under the microscope they are seen to consist of fossil fragments, among which a multitude of little rhombohedral crystals are developed. In the center of each one of these rhombohedrons is a black spot, which, upon close examination, is found to consist of pyrites. Sometimes, instead of a single spot, there is a large number of dust-like particles, which give to the stone a very marked and characteristic appearance. These are so numerous that it can scarcely be doubted that they impart the characteristic color to the stone. That they are situated, however, in the exact center of compact crystalline material cannot but have an influence in protecting them from disintegration, and there is no evidence that the presence of this ingredient has proved deleterious to the stone.

The white underlying limestone is what is called a cutting stone, and can be raised in blocks as large as can be handled. It is more highly fossiliferous to the unaided eye than the blue limestone, but under a microscope it is less so, and there is a much larger number of the rhombohedral crystals which correspond to its more magnesian character.

At Point Marblehead the limestone quarries are all located in a terrace lying a few rods from the beach, where the thickness of the formation quarried is from 15 to 25 feet. Already 20 acres, as estimated, have been excavated to this depth.

These quarries are among the most famous of northern Ohio, and their location directly on the shores of lake Erie, and the heavy stones

that some of them produce, have led to very large use of the stone, especially in the government works along the line of the great lakes. Latterly they are losing their place as building stones to some extent, but the production of lime has increased. Some quarries have been worked for at least fifty years. In these quarries the lower 6 or 8 feet are cemented into one solid sheet from which the large dimension stones for which the location is famous are extracted. It is from these quarries that a large part of the heavy stone used in the Sault Ste. Marie canal, in the northern light-houses, and in other government works has been derived. Many of the most important public and private structures in the region of the great lakes were built of the Marblehead stone. The Detroit and the Cleveland water-works, the light-houses at Spectacle Reef, Marblehead (built over fifty years ago), and Stanard's Rock, Lake Superior, were all wholly or partly built of this material. It is particularly valuable in situations where it is exposed to the action of water or frost, as is shown by the condition of the old locks of the Sault Ste. Marie Falls canal and the light-houses in exposed situations.

The material from these quarries, like that at Sandusky, is a magnesian limestone, which contains beautifully preserved fossils; the centers of the little rhombohedral crystals that characterize all of the Sandusky limestone are free from the grains of pyrites which characterize the blue Sandusky layers, and the difference in the color of the two stones is to be attributed to this circumstance.

The following analysis, made by Mr. J. Lang Cassels, represents the composition of the limestone from these quarries:

	Per cent.
Calcium carbonate	83.20
Magnesian carbonate	15.83
Silica	0.15
Organic matter	0.02
Moisture	0.80
Total	100.00

The proprietors claim that they could easily extract a block of stone equal in size to the Egyptian obelisk recently introduced into this country, its extraction being simply a matter of expense.

The block-stone proves to be a source of excellent lime, which has long been used, but which of late has been more abundantly produced.

All of the waste material is devoted to this purpose, and nothing remains in the quarries except flint nodules. The modern kilns of the best construction are attached to some of the quarries, and 300 or 400 barrels per day are turned out from one single quarry. Part of the thin stone goes to lake Superior for furnace flux, where it is highly esteemed, and a large trade in the lime has been built up at Duluth and in the northwest, and the best stone of the quarries is now being burned. Much of the stone is shipped to other points to be burned, and all along the lakes are kilns which are supplied from Marblehead and Kelley's island. The Michigan Insane Hospital building at Pontiac and the government breakwaters at Erie were constructed of the Sandusky stone.

At White House, in Lucas county, the same lower beds of the Corniferous are worked, and this is the only quarry which is operated to any extent on the Toledo, Wabash and Western railroad between Toledo and Wabash. Some of the material is shipped to Toledo, as there is a demand for it in winter, when, on account of the ice, the stone quarried near Sandusky cannot be shipped to Toledo by water.

Near Defiance there is some stone quarried from the beds on the Miami river, and the same is true at Antwerp. The quarry at White House was not extensively worked until 1879, when the railroad track was laid into it. The cap-rock has been used for ballast on the railroad, so that the stripping is accomplished without expense.

The weathered rock which is used for ballast is from 2 to 8 feet in depth, and this is underlaid by 6 feet of gray-stone in courses of from 6 to 10 inches in thickness, 6 feet of blue-stone in courses from 6 to 18 inches in thickness, and one course of gray-stone 1 foot 10 inches in thickness. The bottom course is nearly uniform in thickness and is used for heavy bridge work. The blue-stone is not of a decided blue color, like that of the Upper Corniferous at Sandusky, but is a kind of grayish-blue.

Napoleon and Defiance, Ohio, and Fort Wayne, Indiana, furnish the principal markets for this stone.

SUB-CARBONIFEROUS.—A quarry situated at Newtonville, about 8 miles west from Zanesville, is the only one in Ohio from which limestones of sub-Carboniferous age are raised for building purposes. There are several large quarries in other exposures of this same horizon in southern Ohio that are worked exclusively for furnace flux and for lime-burning. The Newtonville stone is a beautiful material, very fine

grained, quite even in color, and of great strength. It is very compact, highly fossiliferous, of light gray color, and has thus far shown no ill effects from exposure to the weather. The Muskingum County court-house, at Zanesville, one of the finest in the state, is built from this stone, and it has also been much used for caps, sills, columns, etc., and although the production at present is small, it may at any time be increased with a demand for the material; but at the present time most of the product is burned. A thickness of about 10 feet of stone is quarried, that being the depth to which natural drainage extends. Several feet more of the best of the stone lie below this level, and the thickness of the layers increases with the depth; upon the top there are only very thin beds, while at a depth of 10 feet the beds are 16 or 18 inches in thickness. The material is nearly pure carbonate of lime, containing only traces of iron and magnesia. In its microscopic structure it appears to be quite highly fossiliferous and very compact, containing only small traces of iron pyrites, the oxidation of which imparts the faint yellow color which the stone generally possesses.

Carboniferous.—A quarter of a mile southwest of Zanesville, near the Muskingum river, a quarry has been opened in the limestone of the Lower Coal Measures, from which some material has been extracted which has been used chiefly for caps, sills, and top courses of foundations. The main product of this quarry is burned into lime. It is not used for the ruder purposes of construction, as it is too expensive. The ledge from which this stone is taken is a solid mass of a bluish color, and about 3 feet in thickness. The stripping which overlies the 3 feet of stone is 25 feet thick. The material is a compact, earthy limestone of a very dark color, containing considerable protoxide of iron and very little magnesia. It is very highly fossiliferous and difficult to work, and is called by the stone-cutters hard and plucky.

The outcrops of this stone are found abundantly in the neighborhood of Zanesville, and the material is quite extensively used for macadamizing streets. The national road for some distance west of Zanesville is constructed of it.

In the townships along the Muskingum the sandstone, which is situated below the coal, affords an excellent building stone and is extensively quarried. The Waverly sandstone also occurs in the western portion of the county. The limestones which also occur in the county are, upon the whole, of rather inferior quality for purposes of construc-

tion, and would scarcely be worked if the lime which can be made from them was not of good quality and demanded for construction in the neighborhood.

There is quite a large number of quarries situated in the outcrops of Carboniferous limestone in southeastern Ohio, the products from which are used as fluxes and for burning, but the two quarries which have been mentioned in Muskingum county are the only ones which are of any consequence as producing materials of construction. The Carboniferous limestones of this area are hard to work and do not possess the highest requisites of a good building stone, but these quarries are capable at any time of producing material for building, and in fact do so, under special circumstances. Although these quarries are worthy of consideration in connection with their ability to produce building stones, still the industry is so insignificant that it has not been considered important to tabulate the products of any of them.

To recapitulate: The line drawn nearly through the center of the state from Erie county on the north through Adams county on the south will form the boundary between the area to the east, in which the chief quarrying industry is devoted to the extraction of sandstones, and the western area, in which the only quarrying industry is devoted to the extraction of limestones.

The geological formations in the limestone area follow one another in a quite regular order, the oldest being situated in the southwestern corner, and the youngest in the eastern part of the state; and the character of the stone is entirely dependent upon this geological arrangement, as regards both the character and the quality of the material.

A considerable quantity of stone is extracted from the Cincinnati group, but, as already indicated, this is chiefly owing to the circumstance that the material is in the neighborhood of the large city of Cincinnati. In quality the material is surpassed by the stone from other formations. A narrow band of Clinton limestone surrounds the area of the Cincinnati group, but at the present time this formation furnishes no building stones.

The Niagara or Cliff formation, which succeeds, is one of the great building-stone formations of the state, and in numerous places most excellent and durable materials are obtained; but even the subdivisions of this group determine largely the character of the stones extracted. The lowest or the Dayton formation produces at all points a hard, com-

pact, light stone, while the Springfield division produces a less compact, more easily worked stone, and the top beds are almost universally converted into quicklime.

The Helderberg or Water-lime rocks, which cover a large area, are almost without exception bituminous dolomites, but in character vary from dark to light and from compact to open or vesicular. The Corniferous limestones are most extensively quarried in and about Sandusky, and furnish one of the finest materials obtained in the state, while all of the overlying formations are almost devoid of building-stone quarries. As regards composition, the stones from these various formations vary from almost typical limestones to almost typical dolomites, and there seem to be no rules which will enable one to decide upon the quality or durability of the stone from its composition. Experience also demonstrates that the composition, as regards the proportion of lime and magnesia, does not determine the value of the stone as material for the prodution of quicklime, and it would therefore appear that the value of the stone is more largely dependent upon its accessory constituents and its microscopic structure.

There is a progressive increase in the amount of magnesia from the Lower Silurian limestones to the Corniferous. The Cincinnati limestones of the Lower Silurian contain from 1 to 5 per cent. of magnesian carbonate, while the Clinton limestones of the Upper Silurian contain on an average about 12 per cent. The Dayton limestone of the Niagara period contains about the same amount, while the upper divisions of the Niagara and the Helderberg formations are made up mainly of nearly typical dolomites. As regards composition the next following Corniferous limestones are very variable. At Bellefontaine the stone is a dolomite, and at Columbus it is as good a limestone, containing on an average 93 to 95 per cent. of carbonate of lime, and the Hocking Valley furnaces are largely using it for a flux.

In structure there is less diversity in the Ohio limestones than in those of some of the other states, since the oölitic and concretionary forms do not appear; but all other types are found, and therefore the greatest diversity exists in the ease with which stones may be worked. There are the open, porous varieties, and the varieties which once were open and porous, but which have been again partially consolidated by the filling of the pores; others in which the pores have been entirely filled; and other varieties in which large crystals have developed them-

selves in a ground mass, giving to the stone a porphyritic aspect. There are the compact fossiliferous stones and the compact non-fossiliferous stones. As regards colors, they vary from very light to very dark, but all possess the drab, gray, or yellowish tints which are characteristic of what are called limestones.

In microscopic structure the limestones of Ohio can all be classified according to certain types of structure which are found to be correlated with composition. It may be at first remarked that the microscope indicates that the stones are all highly crystalline. A crystal is a body which possesses a definite internal molecular structure, and if it is further assumed that the external crystalline form is a property of crystals, then many Ohio limestones are more crystalline in their structure than are the so-called highly-crystalline marbles; for in a great many cases the very well developed crystals with external planes are developed in the mass of the stone, and in other cases the stone is entirely composed of such crystals with the form characteristic of the species of the mineral which composes it. In no case has there been found in any Ohio limestone anything which could be called in any correct sense of the word uncrystalline; and indeed, in the light of microscopic study, any distinction which can uniformly distinguish a limestone from a dolomite is very difficult to find. The progressive increase in the amount of magnesia which is contained in stones is indicated in the microscopic structure by the development of little rhombohedral crystals the sections of which appear quite conspicuous with their sharply-defined edges.

NOTE.

From the statistics gathered by the tenth census of the United States, it appears that Ohio ranks first in the value of building stones quarried in 1880. There are 250 quarries in the state, the output of which exceeds $1,000 annually. The following interesting table was prepared by Mr. T. C. Kelly of the Smithsonian Institution, for "The Builder," of May, 1883.

The States producing building stone in 1880 rank in the following order as to total production of all classes of stone, the value given being that of the stone in the rough at the quarry:

1.	Ohio	$2,541,647
2.	Pennsylvania	1,944,208
3.	Vermont	1,752,333
4.	Massachusetts	1,711,104

5.	Illinois	$1,342,572
6.	New York	1,261,495
7.	Maine	1,259,068
8.	Connecticut	1,087,425
9.	Iowa	670,754
10.	Indiana	633,775
11.	Rhode Island	623,000
12.	Missouri	613,000
13.	New Jersey	514,420
14.	Virginia	410,678
15.	Maryland	346,629
16.	New Hampshire	303,066
17.	Minnesota	255,818
18.	Wisconsin	227,065
19.	Tennessee	192,695
20.	California	172,450
21.	Kansas	142,570
22.	Kentucky	92,216
23.	Michigan	79,165
24.	Georgia	68,980
25.	Colorado	50,400
26.	West Virginia	16,689
27.	Nebraska	15,000
28.	Delaware	12,600
29.	Dakota	1,200
30.	Washington Territory	3,044

In an article by Mr. Kelly, in "The Builder," for June. 1883, we gain the following interesting facts: As to the production of marble and limestone in 1880, Vermont ranked first, with a value of $1,340,050; Illinois, second, with the value of $1,320,742; Ohio, third, with the value of $669,723.

In the production of sandstone, Ohio ranked first with a value of $1,871,924; New York, second, with a value of $724,526; Connecticut, third, with a value of $680,200; Pennsylvania, fourth, with a value of $627,943.

In the production of crystalline silicious rocks (granitic rocks), Massachusetts ranked first, with a value of $1,329,315.

In the production of slate, Pennsylvania ranked first, with a value of $863,877.

Lab. test of fruit of clay. Mimic p. 240

CHAPTER IX.

THE CLAYS OF OHIO, AND THE INDUSTRIES ESTABLISHED UPON THEM.

By EDWARD ORTON, Jr.

SECTION I.

The Origin, Composition, Analysis and Properties of Clay.

The knowledge of the composition and properties of clay now current among the clay-workers in Ohio is almost wholly practical, and there may seem to be ground for surprise that such excellent results should have been obtained with so little aid from science, but it is to be remembered that much less has been done for this subject than for parallel industries. The scientific research directed to it is much more scanty in proportion to the interests involved than in almost any similar field.

The literature of a technological subject always represents the progress of science in respect to that subject. In this field it is represented by only one book that is largely useful in American practice, viz., Professor G. H. Cook's Report on the Clays of New Jersey (Geological Survey of New Jersey, Annual Report for 1878). This treatise is worthy of the valuable deposits that it represents, and for the large use of it in this chapter, due acknowledgments are hereby rendered. Much excellent reading on the subject is contained in the various scientific journals of the day, but this source is inaccessible to many, and but little connected information can be obtained from it.

What work has already been done has proved very valuable, and further study, particularly in a virgin field like Ohio, cannot but be productive of good. In many respects the field is different from New Jersey, as for instance in the geological horizon of our clays, which are all coal measure formations, and a careful study of it may be expected to throw light on many points of interest.

Clay, instead of being a mineral formed by the ordinary processes of chemical synthesis, is the result of decomposition of granite rocks, or by a closer definition, is the result of the decomposition of feldspars or those rocks which yield them, notably granitic and gneissic rock. Orthoclase, the feldspar from which the body of our clays is derived, is a double silicate of potash and alumina; the other feldspars found accompanying it are albite, or the soda feldspar, and oligoclase, the soda-lime feldspar; these latter forms are in small proportion compared to orthoclase. Ordinary aqueous and atmospheric agencies are sufficient to decompose feldspar, giving rise to hydrated silicate of alumina or kaolin and a soluble salt of potash, which is carried away by the water which accompanies decomposition. Feldspar beds are fruitful sources of the finest kaolins and china clays, and are rarely found without some kaolin accompanying.

The mineral elements in granite and gneiss, as is familiar to all, are quartz, feldspar and mica. The first mineral is not affected by air or water, but the feldspars and to some small extent the micas, are attacked by the atmosphere. When the feldspar decomposes, the bond which holds the other elements together is gone, and the quartz and mica are carried off by water or mixed with the clay in varying proportions as the conditions of formation vary. The more the water carries off, the purer the clay left behind.

The irregularity of composition which is so characteristic of clay, is thus seen to be the result of the differing mechanical conditions which surround the clay as it forms; it is distinctively a mineral in which other forces than chemical affinity have left their mark; and another element of uncertainty is added in the fact that if the mechanical conditions were constant, clays would vary with the parent rock, which has no fixed structure.

Thus is exposed, in the origin of clay, the reason of that irregularity which has so long baffled or retarded progress in its study, but which, once understood, proves the key to all that follows.

Chemical constitution claims the first attention in a study of clays, for in it lie the secrets which control its properties and qualities, to know which is the aim of all investigation. A knowledge of this subject renders possible a comparison of clays as to their value for any uses, selection of clays for special adaptations, insures sale of a worthy article to well informed purchasers, and relieves us from the tyranny

of thumb rule. With all the aid that it can render, practice is still empirical and blind, but without it, how much worse. The real value of analysis has never been tested in Ohio, or rather the analyses heretofore used have been the cause of the present distrust of their value. The older methods of reporting analysis yield but little to any but an expert. The fault is this: the elements are put together in a way that recognizes no structure; in fact, it rather conceals than brings it to notice, and those bodies are not classed together which are alike in nature or effect, so that predictions as to the qualities of clay have met with so little confirmation in experiment that practice has almost abandoned the use of such tests.

A few years ago, clays were believed to be what analysis indicated them; silicates of alumina with no definite relation of base to acid and no two having much in common. But the study of their origin proves that clays are mixtures of a real clay, or kaolin base, with various sterile matters accompanying it in the parent rock. When this view was first announced, that one base is common to all clays, analysis was used to combat it. But in the work of the New Jersey Survey this point has been proved, and a mode of analysis used which illustrates composition, structure, and quality as well. The proof of the point was very ingenious and convincing. The standard analysis of pure kaolin was compared with the average of the best New Jersey kaolins; laying aside the impurities of the latter and recalculating on the basis of one hundred; the two agreed very closely. Then in the analysis of common clays silica was divided into free silica or quartz, and that combined in the clay. Taking the combined water, combined silica and alumina, and calculating into per cents, it was found that the kaolin ratio was again obtained, and though some are too aluminous and some too silicious, still none vary widely, and the important conclusion is proved, viz., that kaolin is the base of all clays.

The variations in the clay or kaolinite base, as it is now called, may be due to (*a*) free hydrated silica in the clay, (*b*) undecomposed feldspar, (*c*) other silicates than the normal one; as, silicates of lime, etc., (*d*) formation from other feldspars than orthoclase, or (*e*) errors of analysis; any of which grounds can explain some variation. One ground is very probably a constant source of error; free hydrated silica is believed to be present in nearly all clays, but chemical analysis is not able to determine its amount with accuracy.

There can be but little generalizing as to the tendencies of the different qualities of clay to be out of the kaolin ratio or in it. The comparison of a large number of results obtained from such analysis has yet to be undertaken.

The mineralogical structure, then, appears to be worthy of consideration, as well as the chemical one, in examinations of clays with reference to their value.

The minerals going to compose clay are kaolinite, quartz, mica, feldspar, oxide of iron, lime and magnesia, probably as silicates, the alkalies, probably present in the mica and feldspar, sulphide of iron, titanate of iron, and various rare constituents such as cobalt, copper, zinc, etc.

It must not be supposed that all of these minerals are found in each clay, but such minerals are found in examining any considerable number of clays. Kaolinite, as already mentioned, is a hydrous silicate of alumina, having a percentage composition of

Silica ($Si\ O_2$)	46.3
Alumina ($Al_2\ O_3$)	39.8
Water (H_2O)	13.9
	100.0

which is represented by the chemical formula

$$Al_2\ O_3,\ 2\ Si\ O_2 + 2\ H_2O$$

When pure, it occurs rarely in small pearly scales or plates of a definite crystalline shape, but commonly it is found in large masses of a mealy nature. It is white or nearly so, sometimes with a pearly lustre, and sometimes with none, and an unctuous, soapy feel. The properties which make ordinary clay so valuable are of course characteristic of this body in a greater degree.

Quartz is one of the impurities in clay which is always present; no clay is free from it, though the finest kaolins in New Jersey show only two-tenths of one per cent. In the other extreme there is no well-marked line between sandstone and clay; since almost any sandrock shows alumina and water which immediately indicates the presence of clay, so that it is hard to say where the sandy clay ends and the clayey sandrock begins. Quartz is in grains varying from $\frac{1}{30}$-in. to dust in the finest state of division; occasionally pebbles of large size are found in clay, but the body of the quartz present, falls between the limits assigned. It is beautiful white sand, with its edges perfect and sharp, and that which is

removed from the washing machines used in purifying clays finds ready sale to the flint mills for making potters' silica.

Feldspar and mica are found in very many clays, particularly in those which have never been transported far from the parent rock. In clays which have been much disturbed before settling to the beds in which we find them, mica is not likely to remain in large amount. Feldspar acts as so much sand, except in its tendency to kaolinize whenever conditions favor.

Since both these minerals are sources of potash and the alkalies, it is highly probable that they are the source of these bodies in clays; it is certain that they frequently are. It is rather hard to picture the free hydrate or even the soluble silicates of potash existing in bodies which owe their present structure and position to slow deposition in water.

The hydrated sesquioxide of iron is common to all clays in greater or less extent. Even in the whitest of china clays some iron is always obtained. A recent example in the laboratory of the State University showed more than one per cent. in a silicious clay of snowy whiteness, though that amount is usually sufficient to color a clay to a buff or yellow tint. Iron is the great coloring agent in clays, and makes all tints from lightest buff to cherry red. It is probable that ferrous oxide and silicates of iron exist in clay, in which state they give it a blue or gray tint. Iron is found in all amounts from traces up to seven or eight per cent., or possibly more. The red brick and tile clays of the drift frequently run over five per cent.

Lime and magnesia are found in small and persistent amounts in nearly all clays. In the clays from which the famous Milwaukee cream-colored bricks are made, the proportion runs up to twenty-three per cent. carbonate of lime, and seventeen per cent. carbonate of magnesia, with nearly five per cent. of iron. The average brick clays of the drift show from three to ten per cent. of lime, and in these uses it is a valuable agent, but it would be quite fatal to any of the higher uses of clay. The alkalies, *i. e.*, potash, soda and lithia, are found in all clays in greater or less extent, though not all together by any means. Potash is most common and most detrimental, lithia is most infrequent and in the smallest amounts. Its presence has not heretofore been noticed as an element in Ohio clays, but once detected, it was found in a number of samples. Mention has been made of mica and feldspar as the probable sources of the alkalies in clays, and this theory is strengthened from the fact that the largest

source of lithia at present is one of the minerals of the mica group, viz., lepidolite.

Titanic acid ($Ti O_2$) has long been known as a constituent of some clays, but the report of New Jersey was the first to bring its unfailing presence to light in the clays of those districts. Reports of its discovery have from time to time, for thirty or forty years past, been circulated, but it failed to excite much attention. But its presence in small but persistent amounts is a constant factor in the later analysis. The source is believed to be menaccanite or titanate of iron, and experiments made by Cook strengthen that view. The amount varies from one or two-tenths per cent. to two per cent.; it is believed to be as neutral as so much sand would be in its effect on the clay. If this element is not reported in analysis it makes an error in both alumina and silica, as it fails to go to either perfectly.

Sulphide of iron is an occasional constituent of clay, but has not yet been noticed in Ohio. The other source of color noticed in clays is organic matter. The shades produced are all of a bluish-gray running to black and disappearing when the clay is burnt. The purer flint clays, like those of Portsmouth and Mineral Point, show a peculiar striping and veining which looks like concentric circles of vegetable growth. The color of the clay is light gray, and the veins dark blue, yet all turns to the same buff tint after calcination. In New Jersey, vegetable matter is frequently present in lignitic masses, but none of this is seen in Ohio. Organic matter does no harm unless the porosity produced by its expulsion is a disadvantage, but saw-dust is often added to clays in which porosity is a desired element.

Rare minerals containing such metals as cobalt, copper, zinc, and such salts as phosphate of iron are met in clays, but are exceptions and are of no importance in practical work. Thus it appears that mineralogically, clays are kaolinite, mixed with sand, colored by iron and organic matter, and showing varying amounts of feldspar, mica, and other silicates and titanates. The chemical investigation of a clay should endeavor to present these facts, besides grouping those bodies together which are similar in action and effect.

The following analyses, part of which were made in the Laboratory of the State University for the Geological Survey, and part from various sources, will indicate, it is hoped, those points which have been emphasized in the foregoing discussion. They are, as will be seen, on the

TABLE OF ANALYSES OF CLAYS.

FIRE CLAYS.

Number.	Name of Company and Location.	Combined Silica (SiO_2). 1.	Alumina (Al_2O_3). 2.	Combined Water (H_2O). 3.	Per cent of the Kaolinite Base. 4.	Quartz (free SiO_2). 5.	Titanic Acid (TiO_2). 6.	Total Sandy Material. 7.	Sesquioxide of Iron (Fe_2O_3). 8.	Lime (CaO). 9.	Magnesia (MgO). 10.	Potash (K_2O). 11.	Soda (Na_2O). Lithia (Li_2O). 12.	Total deleterious impurity. 13.	Moisture. 14.	Sum Total. 15.	Remarks. 16.
1	C. E. Holden, Mineral Point	35.39	31.84	11.68	78.91	17.13	1.68	18.81	.67	.50	.19	.59	.00	1.95	.69	100.36	N. W. Lord, Chemist.
2	Scioto Fire Brick Co., Sciotoville	43.78	40.82	13.77	97.97	...	...	...	with Al_2O_3	...	...	...	...	...	.82	98.79	N. W. Lord, Chemist, unfinished.
3	Scioto Star Fire Brick Co., Sciotoville	53.07	34.46	10.30	97.83	with clay.	...	...	1.60		.57			2.17	...	100.00	G. A. Mariner, Chemist.
4	Scioto Star Fire Brick Co., Sciotoville	52.36	33.54	12.28	97.98	"	...	...	1.02		1.00			2.02	...	100.00	G. A. Mariner, Chemist.
5	Scioto Star Fire Brick Co., Sciotoville	52.56	34.80	10.50	97.80	"	...	...	1.00		1.20			2.20	...	100.00	G. A. Mariner, Chemist.
6	Scioto Star Fire Brick Co., Sciotoville	52.00	34.78	10.94	97.74	"	...	...	1.48		.78			2.26	...	100.00	G. A. Mariner, Chemist.
7	Portsmouth Fire Brick Co., Portsmouth	50.95	39.49	9.18	99.62	"	...	...	with Al_2O_3	.30	.28	.31	...	.89	...	100.51	E. M. Reed, Chemist.
8	Niles Fire Brick Co., Niles	43.88	40.96	13.99	98.83	"	...	...	.82	...	...	...	...	.82	...	99.65	S. W. McKeown, Chemist.
9	Wassall Fire Clay Co., Columbus	60.77	25.74	9.46	95.97	"	...	...	1.61	.89	.63	1.20	...	4.33	...	100.30	J. A. McDowell, Chemist.
10	Island Fire Clay Co., near Steubenville	29.22	24.97	8.90	63.09	31.34	1.30	32.64	1.66	.63	.40	.28	tr.	2.97	1.69	100.39	N. W. Lord, Chemist.
11	Ballou Clay, Zanesville	31.07	26.47	9.96	67.50	27.71	.94	28.65	1.22	.59	.32	.99	tr. Li	3.12	1.04	100.31	N. W. Lord, Chemist.
12	Etna Fire Brick Co., Oakhill	58.25	31.02	10.08	99.35	with clay.	...	...			This	is a flint	clay.			99.35	David O'Brine, Chemist.
13	Etna Fire Brick Co., Oakhill	63.12	26.20	10.72	100.05	"	...	...			This is	a plastic	clay.			100.05	David O'Brine, Chemist.

POTTERS' CLAYS.

Number.	Name of Company and Location.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
14	Brummage's Stone-ware Clay, Roseville	25.60	19.08	5.57	50.25	43.73	.29	44.02	1.26	.60	.63	2.14	.02	4.65	.94	99.86	N. W. Lord, Chemist.
15	Allen's Stone-ware Clay, Roseville	28.61	23.01	8.03	59.65	34.79	.35	35.14	1.50	.41	.62	1.26	tr. Li_2O	3.81	1.97	100.57	N. W. Lord, Chemist.
16	Walker's Stone-ware Clay, Roseville	69.79	19.31	5.08	94.18	with clay.	...	...	...	...	...	...	...	by diff. 4.80	.94	100.00	N. W. Lord, Chemist, unfinished.
17	Uniontown Stone-ware Clay, Perry county	29.35	23.05	7.39	59.79	35.85	.55	36.40	.99	.58	.58	1.45	tr. Li_2O	3.60	1.11	100.90	N. W. Lord, Chemist.
18	Myers, Atchison & Co., North Springfield } Stone-ware.	72.10	19.38	5.13	96.61	...	...	...	...	1.38	.23	...	...	1.61	1.12	99.34	N. W. Lord, Chemist.
19	Myers, Atchison & Co., "	68.24	22.61	5.56	96.41	...	...	...	...	.99	.11	...	...	1.10	1.00	98.51	N. W. Lord, Chemist.
20	Myers, Atchison & Co., "	69.05	21.37	6.00	96.42	...	...	...	...	1.70	.21	...	...	1.91	1.00	99.33	N. W. Lord, Chemist.
21	East Liverpool Yellow-ware Clay	42.28	24.12	7.77	74.17	18.02	1.20	19.22	1.46	.59	.68	2.42	tr.	5.15	.86	99.40	N. W. Lord, Chemist.
22	H. & J. Stripe, Stone-ware, Greentown	72.26	19.23	10.03	98.12	...	...	...	...	...	...	...	...	by diff. 1.05	.83	100.00	N. W. Lord, Chemist.

PIPE CLAYS.

Number.	Name of Company and Location.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
23	N. U. Walker, Walker's Station, sewer-pipe	39.03	27.88	8.87	75.08	15.50	1.26	16.76	2.41	.42	.68	3.31	.12	6.94	.76	99.54	N. W. Lord, Chemist.
24	Freeman Bros., Freeman's Station, sewer-pipe	37.92	30.10	9.95	77.97	13.80	1.35	15.65	1.94	.62	.53	2.74	tr.	5.83	1.05	100.50	N. W. Lord, Chemist.
25	Bolivar Clay, Island Siding, fit for pipe	35.75	28.69	9.67	74.11	16.07	.72	16.79	2.77	.77	1.41	2.57	.25	7.77	1.72	100.37	N. W. Lord, Chemist.
26	Bolivar Clay, Island Siding, fit for pipe	32.45	21.41	6.52	60.38	30.36	1.26	31.62	2.65	.58	.85	2.89	.21	7.18	1.47	100.65	N. W. Lord, Chemist.
27	W. H. Evans, Waynesburgh, drain pipe	16.20	15.89	7.07	39.16	52.69	.16	52.85	2.86	.59	.66	2.23	.29	6.61	1.03	99.65	N. W. Lord, Chemist.
28	A. O. Jones, Columbus, drain tile	14.50	12.63	7.30	34.43	56.80	...	56.80	5.07	1.05	...	...	...	6.12	...	99.35	N. W. Lord, Chemist.
29	A. O. Jones, Columbus, drain tile	15.25	13.22	8.80	37.27	55.10	...	55.10	4.43	1.40	...	...	...	5.83	...	98.20	N. W. Lord, Chemist.
30	Whitmore, Robinson & Co., Akron, Kaolite Slip clay	60.40	10.42	H_2SO_4 .65	H_3PO_4 .09	$CO_2 + H_2O$ 8.05		...	5.36	9.88	4.28	.87		20.39	...	100.00	N. W. Lord, Chemist.
31	Bodine's Pottery, Zanesville, Albany Slip clay	...	...	...	...	...	...	...	1.43	...	...	3.17	.72	5.32	...	...	N. W. Lord, Chemist.

NEW JERSEY CLAYS (New Jersey Report).

Number.	Name of Company and Location.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
32	Loughbridge & Powers, Woodbridge	42.23	39.53	13.59	95.35	.50	1.40	1.90	.50	.10	.00	.41	.08	1.09	1.21	95.55	Used for ware and brick.
33	H. Cutter & Sons, Woodbridge	43.90	38.24	14.10	96.24	1.10	1.30	2.40	.96	.00	.11	.15	.00	1.22	.70	100.56	Used for ware and brick.
34	W. P. Benton, Woodbridge	33.00	23.80	6.70	63.50	29.10	1.70	30.80	1.60	tr.	.57	2.01	.76	4.94	1.00	100.24	Used for sewer-pipe.
35	E. R. Rose, Amboy	29.95	21.07	7.22	58.24	36.75	1.45	37.90	1.47	.30	.11	1.56	tr.	2.44	...	99.58	Used for stone-ware.
36	Noah Furman, Jacksonville	29.46	21.29	6.81	57.56	38.14	1.01	39.15	1.71	.30	.11	1.82	.18	4.12	...	100.83	Used for stone-ware.

ENGLISH CLAYS.

Number.	Name of Company and Location.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
37	Stourbridge, England	30.50	22.52	8.30	61.32	33.65	1.00	34.65	1.43	...	...	.50	...	1.93	2.10	100.00	Glass pots (N. J. Report).
38	Newcastle, England	43.00	30.92	9.62	83.52	10.50	...	10.50	1.98	...	...	1.96	...	3.94	1.70	99.66	Fire-brick (N. J. Report).
39	Stourbridge, England	65.10	22.22	7.10	94.94	organic matter. .58			FeO 1.92	.14	.18	.18	...	2.42	2.18	99.60	Best glass pot clay.
40	Dowlais, Wales	67.12	21.18	4.82	93.12	organic matter. .90			1.85	.32	.84	2.02	...	5.03	1.39	100.54	Best refractory clay.
41	Newcastle, England	55.50	27.75	10.57	93.78	...	...	...	2.01	.67	.75	2.19	.44	6.06	...	99.84	Best brick clay.

CONTINENTAL CLAYS.

Number.	Name of Company and Location.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
42	Gross Almerode, Germany	47.50	34.37	19.00	95.87	...	...	...	1.24	.50	1.00	...	...	2.74	.48	99.04	Glass pots.
43	Coblentz, Germany	50.20	34.13	...	...	...	...	...	.87	.30	.18	.39	...	...	...	...	Glass pots.
44	Soreè, Belgium	41.70	33.50	10.65	88.85	8.20	...	8.20	2.05	...	...	1.40	...	3.45	2.50	100.00	
45	Andennes, Belgium	36.69	34.78	10.73	82.20	9.95	...	9.95	1.80	.68	.41	.41	...	3.30	1.27	96.72	Best Belgian clay, Bischof.

SELECTED AMERICAN CLAYS.

Number.	Name of Company and Location.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
46	Mt. Savage, Maryland	39.90	30.08	7.00	77.58	16 90	1.15	18.05	1.67	...	...	2.30	...	3.97	.90	100.50	Best Am. brick (N. J. Report).
47	Woodland Clay, Clearfield county, Pa.	42.15	31.43	9.40	82.98	10.25	1.60	11.85	1.51	...	.32	2.01	...	3.90	1.20	89.93	Cambria Iron Co.
48	Huron county, Indiana	40.10	36 35	22 60	99.05	.40	...	.40	.15	...	.13	.14	...	.42	...	99.87	China clay. Abnormal amount of [water.
49	Montgomery county, Mo	48.93	40.09	13.80	97.82	.60	...	.60	.88	...	...	.20	...	1.08	.50	100.00	
50	Christy Clay Co., St. Louis, Mo	64.32	22.82	7.27	94.41	...	S .12	...	1.75	.45	.12	.83	.54	3.21	2.98	100.58	Used for glass pots.
51	Clearfield, Pa.	67.95	20.15	6.58	94.68	...	H_2SO_4 .22	FeS_2 .03	1.96	.08	.21	2.04	...	4.19	...	99.24	Fine fire-brick clay. (Penna. Survey.)
52	Blue Ball Clay, Pa	44.55	39.00	13.66	97.21	...	1.70	...	1.44	.02	.07	.53	...	2.06	...	100.98	Potters' ball clay. (Penna. Survey.)
53	Milwaukee Brick Clay	38.22	9.75	1 85	49.82	...	CaO 3.24	FeO 1.16	2.84	$CaCO_3$ 23.20	$MgCO_3$ 15.88	2.16	.65	49.07	.95	99.84	Famous cream-colored brick.

same plan as those of the New Jersey Report; though obtained by a different process. In the first three columns will be found the three constituents of kaolin, in the fourth, their sum, giving the per cent. of real clay in the body. In the fifth, sixth and seventh columns, are the sand, titanic acid and their sum, indicating the sterile impurities of the clay. In the eighth, ninth, tenth and eleventh, are iron, lime, magnesia, potash, soda and lithium, and twelfth, their sum, indicating the detrimental or fluxing impurity of the clay; fourteenth, moisture, and fifteenth, sum total.

The points wherein this report of an analysis is superior to the common method are:

1st. The amounts of true clay in a sample are seen at a glance, while it is not accessible at all in the other method.

2nd. The sterile impurities can be separated and compared with the other properties of the clay.

3rd. The fluxing impurities are expressed in detail and total, and can be considered individually or collectively in their probable effect.

4th. From a number of such analyses, conclusions may be drawn with ease and accuracy, which a less graphic method would fail to present to observation at all.

Method of Analysis.

Weigh out 3 grams of finely pulverized and mixed clay into a platinum crucible. Fuse with sodic carbonate, disintegrate in casserole, acidulate, evaporate *dry*. Take up in strong HCl, dilute, filter, wash, dry, ignite and weigh residue, which is the *total silica*. The filtrate, dilute, and divide into two solutions containing respectively one gram and two grams of clay. Take the large solution, heat, precipitate iron and alumina with NH_4 HO and filter. Dissolve, precipitate in strong H_2 SO_4, reduce with Zn and titrir with K_2 Mn_2 O_8, which gives the iron.

Take the smaller solution, take out iron and alumina as before with NH_4 HO. Boil out excess of reagent, filter, wash and weigh. From the weight, take out the iron already ascertained. The balance is alumina.

In the hot ammoniacal filtrate, take out the lime with $NH_4\overline{O}$, filter, wash, ignite, and weigh as sulphate (Ca SO_4).

In the filtrate, precipitate magnesia with $Na\,H\,PO_4$, and filter, wash in ammonia water, ignite, weigh as $Mg_2\,P_2\,O_7$.

The alkalies are determined by J. Lawrence Smith's method by lime and sal ammoniac.

Titanic acid is determined in a separate portion of clay. Take 1 gram; fuse with pure $Na_2\,CO_3$ disintegrate in hot water, filter and wash. Residue put in casserole, dissolve in HCl, expel with $H_2\,SO_4$ in excess, and evaporate till SO_3 is given off. Cool, dissolve in cold water, filter, wash and boil filtrate for TiO_2, collect, fuse with $KHSO_4$, cool, dissolve in water, neutralize with $Na_2\,CO_3$, and boil as before, weigh $Ti\,O_2$. Half this weight must be taken from both the alumina and silica, as the titanic acid does not go to either completely in ordinary analysis.

The whole value of a knowledge of the composition of clays lies in the insight we gain into their properties and value, but into this most complex study, conjecture and hypothesis still enter in considerable amount.

That the properties of clay depend on its composition is evident. That composition we may easily know, but in the relation of composition to properties is the uncertainty. Besides the effect of chemical composition, the physical structure has weight in determining the properties of clay. Density, though a physical quality, influences greatly the fitness of clays for certain uses. The density of clay varies with its composition and structure. The more quartz it contains, the heavier it is, for the specific gravity of silica is 2.5 to 2.8 and that of kaolin is much less. The mean of nine determinations of good New Jersey kaolins was 1.6. The other elements of greater specific gravity than kaolin are present in too small amounts to have any effect. Besides the composition of clays, their fineness of division and porosity are influential points. It is believed by some that fineness of grain is detrimental to the refractory qualities of a clay, it being held that the finer the grain the more heating surface is exposed in proportion to the mass, but as fineness of division always goes with closeness of structure, the heat has less chance to circulate between the particles of the mass than between the open grains of a sandy clay; hence, it is doubtful whether the effect of a fine grain is beneficial or detrimental in this particular. The density of a clay is an important point in determining its use for those places where it will receive at once both high heat and great pressure. Such wares as glass house pots, which must be refractory, to stand and keep their

shape at the temperature at which they are used, must also hold a heavy charge of fluid glass as well, and the temperature with some variations of intensity must be maintained for weeks at a time. Such pots are made in England of the best Stourbridge clay, which has a specific gravity of 2.45 to 2.55. In our own country, we use a mixture of various native clays, with the famous Gros Almerode clay from Germany, which has a specific gravity of 2.2. The Missouri clays, much used for this line of work, are also very heavy. None of these clays owe their weight to their composition, but entirely to structure. From these points it would seem that fineness of division, entailing as it does superior density, is a benefit to a clay.

Another property of a physical nature is plasticity. With the accompanying property of permanently hardening under heat, it is the quality which gives clay its widest use. Various explanations have been offered, but none are yet advanced which make clear all points. It has been ascribed to the impurities, to the alumina, to the combined water, and to other causes, against each of which, examples can be cited that seem to set it aside as inadequate. The impurities do not appear to cause the plasticity, for the sand acts unfavorably to it. The alumina is not responsible, or kaolins would be the most plastic of all, while the flint clays of Ohio are many of them approximately pure kaolins, and at the same time eminently non-plastic. The combined water exerts some influence it is evident, as its expulsion entails permanent loss of plasticity, but it cannot be the sole cause of plasticity, as clays equally hydrated are just as liable to differ in this respect as to agree. No theory is so well received at present as that advanced by Cook. He shows that the microscope reveals a crystalline structure which the eye does not detect, and that this structure varies greatly in degree of perfection in different samples. Some are composed of masses of hexagonal plates or scales piled up in long bundles or faces and masses of unattached scales nearly perfect. Such clays are always but little plastic, but may become so on mechanical treatment such as grinding and kneading; on re-examination the clay then shows the same elements of structure, but broken and confused, no bundles left intact, scales broken and a homogenous matrix of the crushed material derived from the still crystalline part. Clays are found in all states of this breaking up, from the highly crystalline mass to the homogenous matrix showing no plates at all; and on the degree in which the crystalline structure is retained,

its plasticity depends. This theory is certainly plausible, and is supported by the fact that we always subject our clays to secure increased plasticity to mechanical disturbance which has the effect that the microscope reveals. This view harmonizes with more points than any other advanced as yet, and offers a fair solution of the different degrees of plasticity which plastic clays exhibit, but it does not explain, nor attempt to explain, the differences which exist between flint clays and plastic clays, as Professor Cook's examinations were entirely confined to the latter.

There is no theory worth consideration at present concerning the difference between flint and plastic clays. Suffice it to say, it is no point in chemical composition, or water of hydration, and, as it seems, it must depend on the physical structure of the clay. Possibly it could be studied to the best effect through the microscope.

It has been already mentioned in connection with plasticity, that this property is permanently lost by heating to redness, or by expelling the water of constitution. It is this point which brings in water as an essential to plasticity. The changes which accompany heating of a clay are as follows: First, the complete drying or loss of moisture, which is accomplished by maintaining the temperature at 212° F. for several hours; next, the elimination of the water of constitution, during which the clay becomes rigid and stone-like. When once expelled it can never be taken back. Rehydration is impossible. Though water may be absorbed by brick it can all be expelled at 212° F. After and during the expulsion of the combined water, the organic matter burns out. The matter is not ordinarily found agglomerated enough to cause porosity on expulsion, but is distributed in such a way that its absence merely shows the natural color of the clay.

The expulsion of combined water is nearly always accompanied by a diminution in volume, which varies directly as the water, or the purity of the clay. Pure kaolin shrinks as much as one-fourth of its bulk, it is stated, sometimes even more. The sandy clays used in making sewer-pipe and stoneware shrink from the tempered state from one-ninth to one-sixteenth, usually about one-twelfth. The shrinkage of the raw clay would be very much less, probably not over 3 or 4 per cent.

A clay, when all the water of crystallization is expelled, will not shrink any more at red heat, but with increased heat will shrink more and more up to the moment of fusion. A pure kaolin apparently shrinks

when heated a second time, even if the water is all expelled by the first heat, yet it is practically impossible to fuse it. But a good flint clay containing some sand will lose all shrinkage on being once calcined at white heat. Such clay is then used to counteract shrinkage in a body of green clay, as this effect is obtained by mixing in sand or some non-shrinking body. Many clays contain sand enough naturally to shrink little or none on heating, and some are so sandy as to actually expand, though usually at the expense of soundness of structure; for the particles of clay will shrink away from the grains of sand and this renders the structure very friable.

The qualifications of a clay for common pottery and building material are simple, viz., plasticity when wet, and solidity and hardness when burned, but those products involving the highest qualities of clay, refractoriness, require much sharper tests.

The first requisite is purity, at least purity within limits, and though the other points, density, plasticity, and non-shrinkage add greatly to the value of a pure clay, they can in no degree supply its place.

Infusibility in clays rests in the clay or kaolinite base and its main impurity, quartz. Both are infusible, taken separately in the highest heats obtained in metallurgical practice. Both are fusible in the oxyhydrogen blow-pipe flame, but the kaolin is the more infusible of the two.

Long and intense heat applied to an intimate mixture of clay and silica is apt to result in a silicate of another ratio of base to acid, and which is likely to be fusible. But the great trouble with free silica in clay, in a fine state of division, is the fact that any fluxing agent readily unites with it, and makes a fluid slag; and in a refractory body the fusing of any one part is the beginning of the end.

The impurities most dreaded in a refractory clay are iron and potash; it is hard to state which is most to be feared. Iron is not so powerful a flux as potash, which is the worst of all the common elements, but the iron is present in larger amounts than potash in most clays, and consequently does as much harm if not more.

The effect of the iron is detrimental to the appearance of clayware, and consequently has a direct bearing on the price of goods, while potash shows no more on the surface than on the inside, and when present in the usual small amounts it produces an incipient vitrification

which makes the ware ring like a bell when struck, and is often a help in selling.

The extent to which iron may be present without detriment is a point on which authorities do not agree. The Stourbridge clay of England, acknowledged to be the most refractory clay known, has 2.25 per cent. of iron on an average of 100 analysis, with extremes of 1.43 and 3.63. Gros Almerode clay, has 2.12, Coblentz, 2.03, New Castle, 2.32, and yet all these clays are famous. Test mixtures of iron and pure kaolin have been run higher than this and have stood well, but as a general rule it is unsafe to rely for fine qualities on a clay with over 2 per cent. of iron, particularly if the other impurities are developed in any amount. It is a well-known principle in chemistry that mixtures of bases are much more active fluxes than an equal amount of any one base; so with iron, its effects show worse when in presence of other fluxing agents.

The state in which the iron is present makes some difference; if as the sesquioxide, it takes more heat than when in the protoxide state to combine in the clay, for iron will only combine with silica in the protoxide state, and if that state is already developed, it is easier to combine the sand and iron than if in the other oxide.

Sulphide of iron has a bad effect on the clay since its decomposition gives rise to the lower oxide of iron, besides the effect which the sulphur may have.

Silicate of iron is also detrimental, since it melts at a comparatively low temperature. On a piece of ware, iron in the uncombined state imparts a buff or red color; when combination begins and progresses the ware is of a bluish-gray cast, deepening as the fusion of the iron proceeds, and running to glassy black if much iron is present.

Lime and magnesia act as fluxes on clays, but in Ohio fire clays the comparatively small amounts present makes them but little thought of as detrimental. They are probably present as silicates, and as these are readily fusible, their action is evidently unfavorable. When these bases are present as carbonates they combine at a higher temperature than iron or potash. The Milwaukee bricks, as already noted, are full of carbonates of lime and magnesia, and require a very hot burn, but when once the lime and silica combine they destroy the effect of 5 per cent. of iron, enough to make the clay perfectly black. A brick of this kind presents an even, fine-grained, vitrified appearance on its fracture.

The fusion produced by the alkalies as explained, is not of a kind to excite attention, but when a piece of brick vitrifies to a "body" on burning, it is a sure sign as to its probable action in an exposed position.

The amount of potash which a clay can contain and keep its fire properties is variously put by different authorities. As with iron, pure kaolin will stand a good deal when no other base is present, but a multiplicity of bases makes fusion easy. Titanic acid is regarded as neutral to fire qualities; the form in which it is present being infusible.

The statement of the tendencies and comparative power of the dangerous impurities of clay would lead us to believe we could use predictions as to their result in a given clay with some confidence, but the best practice does not yet trust to analysis alone.

The most complete test of a clay now known would be obtained by use of such analysis as has been described, coupled with a fire test made especially to develop such points as the analysis indicates to be weak ones. Fire tests are of two kinds—one is subjecting the clay to absolute heat without the action of any accompaniments, and the other is in putting the clay through the course of treatment for which it is designed to be used. The former develops the absolute quality of the clay as good or bad, the latter proves or disproves the fitness of the clay for the work. The latter is better of course as a business test wherever it is practicable to use it. The former can be made only in a specially adapted furnace. The clay is cut into one-inch cubes with square edges, and is set in a covered crucible resting on a lump of clay of its own kind, so that it touches no foreign object. The heat is then applied and its effect will vary from fusing the mass to a button to leaving it with edges sharp and not even glazed on the surface. Experience soon renders one proficient in judging of clays by this test.

The statements now made cover the leading facts in regard to the composition and structure of clays.

SECTION II.

The Clay Deposits of Ohio.

The clay deposits of Ohio may be separated into two well-defined divisions, viz., the clays of the drift, and the far older group that is found interstratified at various horizons among the bedded rocks of the State. In geographical distribution, these two divisions are quite distinct, the former having its chief developments throughout the northern and western portions of the State, and the latter throughout southeastern Ohio, but they overlap to some extent upon the boundary.

The drift region of Ohio, as shown in a subsequent chapter, is bounded on the south by a sinuous line entering the State on the southeast in Columbiana county, and striking the Ohio river in Brown county. There are then in the south and east of the State twenty-one counties in which no upland drift is found.

Drift Clays.

The geological character of the drift is well known. It consists of deposits of sand, gravel, boulders and clay in no regular order. The item of interest to us is the occurrence of the large body of clays, which though of poor quality, as a rule, still play an important part in our economic geology in many ways. The clays occur in shallow surface deposits, accompanied by alternating sands and gravels.

They are distinguished as boulder clays and stratified clays, as their structure varies; only those of the latter class and of homogeneous structure, free from boulders and debris, are suitable for use. Valuable deposits seldom reach a thickness of ten feet and often have a thickness of only two or three feet, but in this thickness extend over acres of ground. Such as are fit for use are plastic, yellow or blue clays, which work very kindly with but little preparation. They are all impure, containing from 3 to 6 per cent. of iron or even more, from 3 to 12 per cent. of lime and magnesia and notable amounts of the alkalies. They are easily fusible, usually to a black glass; when burned but not hard

enough to vitrify, they are red, of various tints. There seems to be a difference in the mode in which the iron is in combination in the clays of the drift and in the fire clays of the State, the coloring due to the iron being not at all in proportion to the amount. A fire clay containing 3 per cent. of iron will be pale yellow in color, while a brick with 4 or 5 per cent. will be a cherry-red. In the fire clay, however, the iron frequently shows in black spots, which would increase the average of the clay in iron without making any difference in its color, since it occurs in kernels and is not distributed. The clays of the drift are of very great value to us, as they are the source from which our building material is largely derived. They are better for that purpose than a purer clay would be, and their uniform plasticity makes their working easy. In another rising industry they figure prominently: that of making drain-tile. There is little or no distinction in the qualities of clay needed for these two uses. Good brick clays abound in every county covered by drift, though their qualities change in different parts of the State. The marks of the districts are not well defined, as the clays change too rapidly and too frequently to make much generalizing possible. Cincinnati has a brick which is different from any found in other parts of the State. It has a dirty white color on its surface which is probably due to the water used in tempering, dissolving some soluble salts of the alkalies and earths present, and leaving them on the outside of the brick. When it is first heated in the kiln, as the fire deepens, the bodies flux the outside of the brick as described; at any rate the outside of the brick has not the even, regular, though light tint which the inside exhibits.

Another trouble of drift clays is the occurrence of lime in small nuggets which the process of manufacture does not remove; these are burned until caustic in the kiln, and then become hydrated when exposed to the air. They burst out, leaving holes in the brick, showing the white lime in the base of the cavity, and make a very unsightly appearance. It is very seldom that a drift clay can be used for anything better than brick or tile, but some earthen-ware, such as flower pots, etc., are produced from it.

Occasionally, however, small patches of clay are found which are noticeable exceptions to this. An example is found at Springfield, Clarke county, where a bed of whitish clay, very similar to the Milwaukee cream-colored clay, is found. It is a bed twenty feet thick, showing

in the cut of a railroad under twenty feet of superincumbent dirt. It makes a beautiful cream-colored brick of fine, even, homogeneous fracture, and fit to be used in connection with the bricks from which our ornamental city fronts are built.

The search for, and mining of, drift clays is of the most primitive kind, as they lie on the surface and are cut in every well. Mining is nothing but digging in low pits, taking everything as the work progresses. The clays are oftenest used in close proximity to the diggings.

Bedded Clays.

The clays which constitute bedded formations present a very different appearance from those of the drift, and have little in common in character. They may be divided into two groups, Coal Measure clays and the lower clays. This last division is made to include the one or two exceptions to the first group which have been noticed. In southwestern Ohio, there is an occasional development of a clay between the Lower and Upper Silurian rocks. In one instance in Miami county, this has been made use of for making drain-tile and the like. The other notable case is found at Columbus, where the decomposed top of the Huron shale deposit is utilized in making sewer-pipe.

The geographical extent of the Coal Measures is bounded by a line somewhat similar to that which bounds the drift. Included within and cut by this boundary are thirty-three counties, but not more than twenty-two hold any large measure of mineral wealth. As is well known, every coal vein carries its bottom clay. This at least is the rule, and the exceptions are rare. In a few cases, coals have a slaty or shaly floor, but this is so nearly clay in nature, that the exception is only apparent. In England frequently, and in Ohio in a few cases, a hard, fine-grained sandrock called gannister, containing 98 per cent. silica and 1 per cent. alumina, underlies a coal seam. Clays without the coals are much more common than coals without clays, and the presence of clay alone usually serves to mark the horizon of an absent coal. Limestone and ores are often also associated with constant deposits of clay.

Some one has said, that the aggregate effect of all the coal deposits of the State would hardly be enough to make one steady, regular seam of moderate thickness over all the coal measure area. Our clay deposits would be perhaps equal to a rather heavy vein of clay over the same territory ; heavy in proportion to the coal at least, for it has much less range in thickness and does not share largely in the fluctuations in

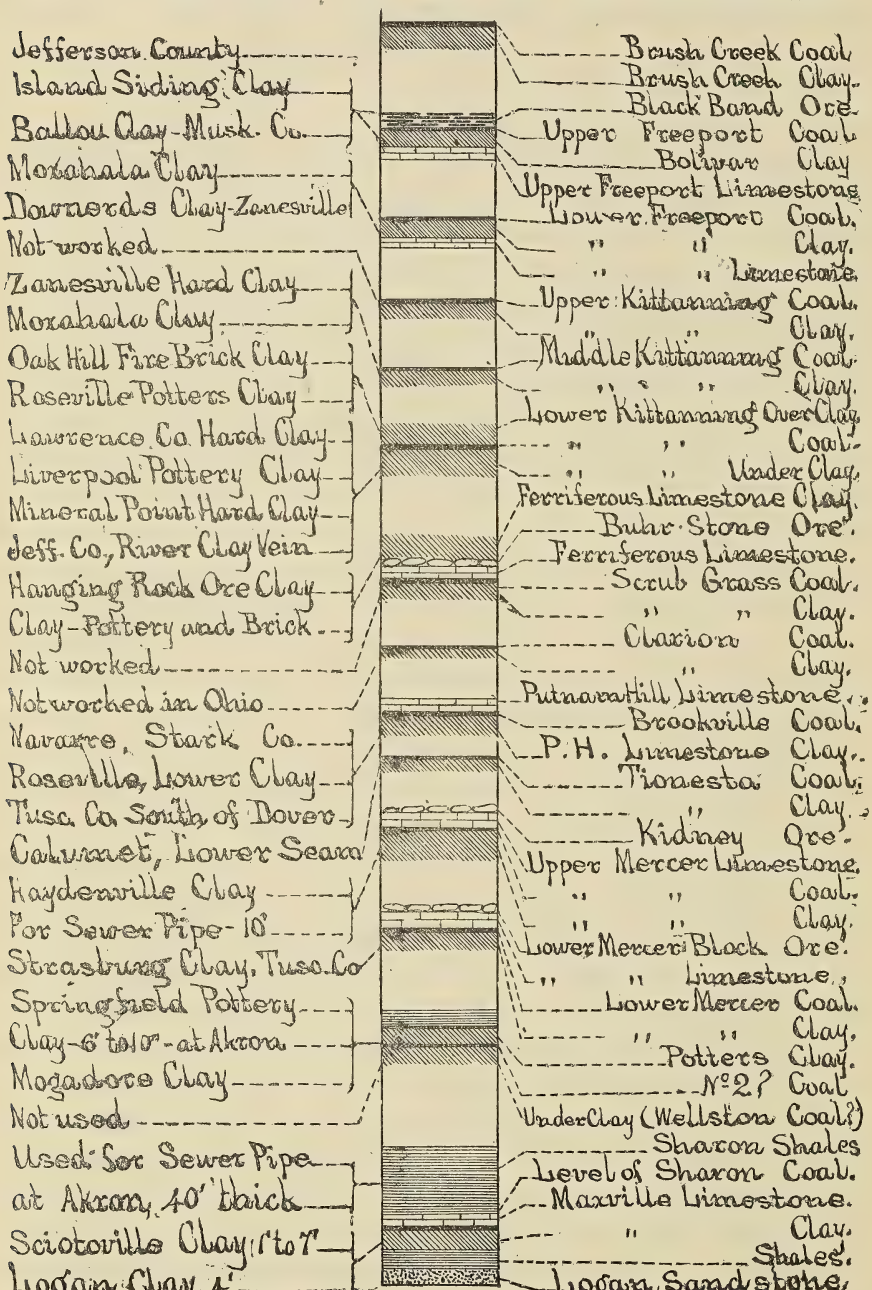
height that the coals exhibit. But such standards of comparison render but little service, because a fire clay is of little value unless of good quality. It is not accessible by cheap means for the common uses and is not so well adapted to those uses as still poorer clays; and the formations at best now yield, in only a small extent of their territory, any sufficiently pure clays for the higher uses.

There are undoubtedly valuable districts of clay in Ohio yet untested and undeveloped. The geological questions as to the source and formation of the clay seams are not by any means well wrought out.

A deposit of fine-grained clay always lines the depression in which peat bogs grow; its fineness and color show that it must have been deposited from nearly still water, perhaps in so fine a state of division that the water which carried it would have been clear to the eye. This much is found in common with coal seams, that a fine-grained clay underlies them also. The similarity in the origin of peat and coal are unquestioned, so that the causes which produce our fire-clay veins are still operating to-day. The coal deposits are miles across and hundreds of miles in linear extent, yet the clay floor is much more constant in volume than the coal. The quality changes constantly, however, and it has no fixed character over any large area. With the questions of formation, the distinction between flint clays and plastic clays again arises. It is hard to understand how clays can be found in the same seam, side by side, mutually replaceable and running in varying proportions in each cubic yard, which are chemically and physically in sharp contrast with each other.

The valuable coal seams of Ohio are mainly in the lower measures, and the clay deposits worked are wholly confined to that group. The following geological section of the Lower Coal Measures has been prepared to indicate the names, order and geological horizon of our clay deposits, previous to a description of each important bed. It is, of course, ideal, covering so large a range of territory as it does, yet it will serve as an accurate general guide. It is drawn to scale, but the intervals are not given; the latter are given in chapter I, with sufficient accuracy for the various districts of the State. The elements which serve as marks from which to identify the clays are mainly coals, but a few limestones and ores are important. These formations and the clays are named in the column nearest the section. In the other column the facts are grouped concerning the clay deposits.

CLAY DEPOSITS OF LOWER COAL MEASURES.



The Coal Measures extend 1000 feet higher than the section indicates, including the Barren and Upper Measures, but no notable coal occurs and no clay bed worthy of mention. The clays of the Barren Measures are mainly red and irony; they have been turned in small quantities to various uses, but have no prominence in any. The clays of the Upper Coal Measures are regularly found under the coals, but are put to no use as yet. They are mostly present in small amounts, and are, like the coals, rarely of any economic value, the Pittsburgh seam being the only one that holds high rank in Ohio.

The lowest clay in the Coal Measures, the Maxville or Sub-carboniferous limestone clay, has its most prominent development in Ohio in and about Sciotoville, Scioto county. This name for the clay is not a recognized one, but its most characteristic associate rock is this limestone, which, in the famous Kentucky clay mines, lies in heavy cliffs just over the massive clay. It is frequently called the Sciotoville clay, as that place is the center of its development and use. The clay underlies the limestone directly or is separated by a thin streak of coal, which is supposed to be on the horizon of coal No. I, or the Sharon coal, but so far no section has been obtained in which the true and unmistakeable Sharon coal and Maxville clay both figure. The deposit is first found in the tops of intersecting ridges near Portsmouth, occasionally overlain by nodules of limestone, but no coal; at Sciotoville, eight miles eastward, the hills are all high enough to hold it and its best development is here; at Webster, thirteen miles further on, it is at drainage level, and shortly after dips under the surface. On the Kentucky shore and for forty miles to the south-east, it has a very heavy development. The clay runs from 1 ft. to 5 ft. thick, averaging 2 ft. 6 in. It is benched where practicable, drifted where necessary, and it is all mined by powder. It is grayish-drab in color, full of blue organic stains, but of remarkable purity and excellence. It is very hard and flinty, but runs soft in places, so that plastic clay need not as a rule be imported.

Another small development of this clay is found near Logan, Hocking county, where it supports the manufacture of a good fire brick. Its main development is to the north-east of Logan, but in various places to the south-east it is also mined. It disappears under drainage three miles north of Haydenville. It is about three feet thick, and quite pronounced in character as a flint clay. The western townships of Vinton county also hold this clay in fair development, but at present so far from rail-

roads as to be inaccessible, though it cannot fail to be of value at some future time.

The under clays of the unmistakable Sharon coal in Mahoning county, Massillon and Jackson, have nowhere been found valuable, so far as known. The shales which overlie the Sharon coal in some places form in one instance the material upon which an immense manufacturing interest depends. The well-known Akron sewer-pipe is made entirely from these shales, which are not often used for such work. Their employment probably began in the use of the soft plastic clays of the out-crop, due to the decomposition of the shale. As these gradually failed, the less weathered material was called into use, until now the unaltered shale is the main reliance. It occurs in beds forty feet thick in some cases. It is cut by frequent joints, and is very easily mined. It lies just above the place of the Sharon coal. At Tallmadge this coal has been mined in close proximity to the shale pits. The shales are in composition much like a silicious brick clay, having a large per cent. of iron which gives the cherry-red fracture found in all the Akron pipe.

The potters' clays of Springfield township, Summit county, are among the best natural beds of stone-ware clay in the State. They are referred a little doubtfully to the horizon of coal No. 2, or the Quakertown seam, as the Lower Mercer limestone is formed about fifty feet above them. The clay deposits are from 6 to 10 feet thick, overlain by shales and a hard sandrock, and underlain by shales and occasionally by an inch or two of coal. The clays are of several grades of excellence; the poorest or "chuck" clay, which is commonly rejected, is found on the top of the bed. The beds are found close to the surface in the largest part of the territory. They are mined by long pits or trenches by which the whole area worked is taken clean, and the refuse is piled back. In one or two instances the clays are mined by drifting, which gives a much cleaner product than the customary way. The district in which these clays are found is small, all the workings being at one place, viz., North Springfield, Summit county, where there are twelve or fifteen banks. They supply all the Mogadore, Tallmadge, Cuyahoga Falls and Akron stone-ware potteries, which make at least twice as much stone-ware as any other district in Ohio.

The clays underlying the other coals supposed to be the equivalent of the Quakertown coal, notably the large coal at Wellston, Jackson county, have never been reported as valuable.

The Lower Mercer horizon furnishes but a small amount of clay at present to the manufacturing establishments; at the Springfield clay banks the limestone clay cannot be distinguished from the potters' clay by eye, but all potters carefully avoid it. Another development of the Mercer clay in south-west Hocking county, on the contrary, shows a very fine potters' clay, and it forms the basis of a large neighborhood manufacture of stone-ware. The locality is peculiarly inaccessible, and its processes are correspondingly primitive. The locality referred to is the Potters' Ridge of Hocking and Vinton counties. At the brick works of Wagner, Wentz & Co., three miles north of Dover, Tuscarawas county, on the C. L. & W. R. R., the clay of the Lower Mercer coal is quite largely used as a bond clay and for third class fire-brick. It lies under 6 feet of fine blue limestone and 18 inches of coal, in a bed from 12 to 15 feet thick; it is too hard to pick by hand, but is readily plastic under treatment. It is mined by drifting, and only about 8 feet are taken. There are many places where clay of this character could be found at this horizon, but without the presence of hard clay near by it is not particularly valuable.

The Upper Mercer horizon is still less serviceable. At Haydenville, Hocking county, there is a fine deposit of silicious clay, which belongs probably to the Upper Mercer level. A blue limestone is found ten feet below, and a coal streak parts it into two strata. Above it comes the regular vein of Upper Mercer coal 24 inches thick. There is a large establishment in process of erection at this point for manufacturing sewer-pipe, for which purpose the clay seems eminently fitted. This is the only development near by, or in other parts of the State of this horizon in which the clay figures.

The Tionesta clay finds but little use in any district, the only well-known instance being at Calumet, Jefferson county, where it furnishes material for a large sewer-pipe and brick industry. It was at first expected to make the Lower Kittanning clay the basis of manufacture. The shaft by which this clay was reached was continued down 100 feet further without definite purpose, when a bed of clay 12 feet thick was struck. It is overlain by shales, and occasionally an inch or so of coal, and it runs sometimes to the great thickness of 18 feet. The system of mining here is better defined than in any other part of the State. The entries are driven in straight lines, the rooms turned off at regular intervals and at right angles to the entries. Entries and rooms are

18 feet wide; no props are used, and the pillars are left 40 feet thick of solid clay.

The next clay met in the ascending series is the Brookville clay, which is a serviceable one in several places. At Navarre, Stark county, an extensive bank is worked. The clay underlies the Brookville coal (coal No. 4 of Newberry), which is in turn overlaid by the Putnam Hill limestone beds. The clay is quite silicious, but makes a good No. 2 brick. It is mined by drifts. To the south of Dover, in the Tuscarawas Valley, this clay is always present, and often of good quality. It is mined near New Philadelphia and below in several places, and used at the brick-works. At Roseville, Perry county, the center of the second largest stone-ware district of the State, the clay used is a mixture from this horizon and that of the Kittanning clays. The lower clay is quite sandy, and light in color; it is found separated by sandy beds, and shales 21 feet thick from the gray or Putnam Hill limestone. It is possible that it represents the horizon of the Tionesta coal instead of the Brookville. It is mined in several localities near by, and is usually only 3 or 4 feet thick.

The next coal horizon, that of the Clarion coal, is poorly represented in this State; clay from this level is used at but a single point, viz., Robbinsville, Columbiana county. The clays of the Scrubgrass coal, which underlies the Ferriferous limestone, are utilized in Lawrence county. The clays are sometimes hard and flinty, but usually are second grade. They are mainly applied to fire-brick manufacture. Just above the Ferriferous limestone, in Lawrence county, directly on top of the limestone ore, occurs a massive deposit of so-called whitewash clay, which marks the level of the ore on every hill for miles around. The clay is dug and thrown off to get the ore, and the weathering agencies soon give it the peculiar white appearance from which it derives its name. The deposit changes character to the southward, and at Ironton appears frequently as a flint clay. The clays overlying the limestone, shade off into a shaly band, which separates them from those of the Kittanning formation. The distance from the limestone to the coal is only eighteen or twenty feet, and the space is often filled with various grades of clays belonging to both levels. The limestone clay is used for brick, pottery and pipe, to some extent. This locality presents an inexhaustible supply of clay, amply good enough for any second class work; mixed with hard clay, good enough for *any* use.

The deposits heretofore described are all quite local developments of the clays of the various horizons. The growth of the next coal vein was accompanied with the deposition of the best marked clay beds of the whole series. The whole horizon for twenty feet above and below the coal is filled with clays. The horizon is not only marked as the level on which clay occurs in large amounts, but it is of more economic importance than any other in the value of its deposits. It produces very fine flint clay, yellow-ware clays, stone-ware clays, admirable pipe-clays and good second class brick, and terra cotta-ware clays.

The first district of Kittanning clays met on entering the State from the east, is the yellow-ware beds of Liverpool and Wellsville. The vein, here well up in the hills, through a low arch in the series, is plastic and easily mined, and it is reached mainly through drifts. It underlies the Kittanning coal directly. The clay, after washing, is singularly free from specks and granules of iron, which are the great trouble in yellow-ware clays. The next district is the Jefferson county pipe works, which line the Ohio river for twenty miles, from Wellsville nearly to Steubenville. The Kittanning clay is here called the clay vein; it is regularly excellent in quality; easily found and at convenient levels for mining, in all the upper works, but gets a little below the railroad level in the Southern Works. It is rather sandy or silicious, quite hard at first, but quickly slacking on exposure; is plastic and readily moulded after grinding, and makes a superior pipe, and a very fair brick for boiler settings, forges and all second class work. The clay extends up Yellow creek, beyond Irondale, where it is still of good quality, and is in constant use. There are no exposures of clays on this level in Carroll or Stark counties or north of Columbiana, but in the northern part of Tuscarawas county, at Mineral Point, the Kittanning clay appears in a new and valuable phase. It is found as a very hard and fine flint clay, suitable for making any refractory material. It is used for retorts, glass pots, brick of finest special grades, etc. It is found about three feet below the Kittanning coal, separated from it by worthless clay. There can scarcely be a more beautiful or faultless stratum of clay than the hard clay of this place. It lies in a band $3\frac{1}{2}$ feet thick, showing faces smoother than the most regular coal; it is so hard that chips from a pick blow will cut the hands of the miner; it is of a light-drab tint burning to a light-cream color; it shows the blue concentric venation of organic matter noticed in the flint clay at Scioto-

ville. The mining of this clay is carried along with the mining of the coal, both being taken out of the same pit-mouth. The coal is usually worked first and then the clay ; the latter being at a lower level, gives the best of ventilation and drainage. There is enough plastic clay occurring with the flint to allow its perfect working. This bed of hard clay marks the Kittanning horizon from Magnolia, Carroll county, to below Dover, Tuscarawas county, where it disappears. The whole formation is absent in nearly all Coshocton county. In Muskingum it reappears at Zanesville and Roseville, carrying the clay from which the stone-ware of that district is made. The coal is usually absent, leaving the clay, hence some question can be raised as to whether the clay lies under or over the coal. From its distance to the Middle Kittanning coal, it seems probable that it is above the coal. This deposit extends from north of Zanesville to below McLuney, in Perry county, and towards Deavertown, Morgan county. The next developments are found in Gore, Hocking county, where clay of a plastic grade from this horizon is mined and shipped to Columbus for pipe-clay, etc. This is merely a local use of this horizon. In Vinton county no clay is mined at any horizon; in Jackson county the Kittanning clay is again found in the Oak Hill mines. The clay here lies on a three-foot stratum of hard and soft clays just over the coal. The most remarkable mixing of hard and soft clay to be found in the State is seen in this case ; no two volumes of clay run alike in proportion. The clays are not used in any other place in the county. In Lawrence county, the Kittanning horizon is well developed. It gives both hard and soft clays above and below the coal; it furnishes clay of much the same grade as the clay above the Ferriferous limestone, and which is applied to the same uses. It is mined extensively at Newcastle and along the river for shipment to Cincinnati. The importance of this horizon can now be estimated since it is seen to figure in workings in every county on the line of its outcrop in which clay is handled at all; and also from the varied forms it presents and the varied uses to which it is applied.

The Middle Kittanning clay is also worked in a few cases, though its developments have none of the characteristics that attach to the lower coal. The clay is used at Zanesville in small extent in the fire-brick works; it is a hard clay of inferior quality. Also clay is shipped from Clay Bank Station, three miles north of Moxahala, which is mined just under this coal; it is soft and of fair quality.

The horizon of the Lower Freeport coal is productive of good clay in two districts; one is at Zanesville, where it is opened at Downerd's Bank, the Tile Works Bank, and at several other places. The clay is of second grade, plastic and quite ferruginous. The other district is at Moxahala, where the Pyle clay is referred to this horizon; it is mined and shipped by cars largely to Columbus. It is a clay of second rate in part of its territory, and in other portions plastic; it is a high grade No. 2 clay. It carries red oxide of iron enough to discolor it and to affect its character for refractoriness, doubtless, but portions of it are excellent.

The Upper Freeport horizon, in one or two places, is found to yield valuable clays; the best is found near Taylorsville, Muskingum county, where it is called the Ballou clay; it is here a hard clay of some value. It is carried to Zanesville for the Fire-Brick Works. At Island Siding, Jefferson county, the same clay is mined; here it is called the "Bolivar clay"; it is mostly second class, but some hard clay is found in the seam. The arrangement of the elements of this horizon is peculiar; there is a gap of twenty feet between the coal and limestone beneath it, in which the clay is developed.

The higher veins of coal are not used at all and are met only in limited places. No clay from above the Upper Freeport is used in this State unless it be in one mine in Jefferson county, where a small amount of clay is taken from beneath a coal, probably the Brush Creek vein.

The position, extent and character of our main deposits have now been taken up and roughly followed through the State. Much more might have justly been said in regard to these horizons if the limits of space allowed. It should still be borne in mind that the majority of the eighteen beds of clays found in the State are found over large areas of territory, and that the small extent of the districts now turned to account is due not to lack of material, but to lack of demand for the products. The same causes which restrict the extension of workings in deposits of known value, of course still further discourage the exploration of new territory. But when the demand arises, there is no doubt that the supply will be at hand.

SECTION III.

The Clay Working Industries of Ohio.

The manufacturing industries included under this head have attained considerable importance within the last few years, as will be seen by the appended statements.

The first development, of course, began in the manufacture of those ruder articles which require comparatively little skill, and which are a daily necessity; the work has now extended until it includes a large number of the branches of the plastic art, and in many of them a very creditable degree of proficiency has been attained.

The nature of our clay deposits would exclude several branches of manufacture from our territory, if we were to be strictly limited to our own resources, but several of these are nevertheless carried on in a large way on imported material.

The clay working industries may be divided into several well-marked groups, the consideration of each of which, in turn, will form the subject-matter of this section.

The two uses of clay that rise above the rest in importance and general application are the manufacture of pottery and of refractory material. As both of these uses make the purity and the rarer qualities of a clay essential, of course they do not permit so large a development as those processes that are satisfied by clay of grosser quality, notably those for making building material and pipe. The ornamental clay working of course uses less labor and more skill than any of the others.

Pottery.

The manufacture of pottery began in Ohio in very early times, and from the rudely-fashioned clay pots of the first settlers has grown the industry as it now stands. The different grades of pottery are stone-ware, earthen-ware, china-ware, porcelain and ornamental work, all of which are made in Ohio, except porcelain, which is made in very small amount, if at all, in the United States.

Stone-ware is the product of an unmixed natural clay, burned at high enough heat to oblige the impurities to combine with the free silica, and thus cause an incipient vitrification or fretting, without loss of shape. It should be impermeable to water without any glazing on it, but it frequently fails in this point; its color is bluish-gray, and is due to combined iron.

Earthen-ware is a product of very similar clays burned too lightly to vitrify the body or combine the iron; it is of a yellow or red-color, from the free iron, and is porous unless glazed.

China, that is, the ironstone china made in this country, is a mixture of several clays with powdered silica and enough potash feldspar to make the body vitreous on burning. Porcelain is made in the same way but in very different proportions of material, while ironstone china is thick, and opaque porcelain is often thin as an egg-shell and nearly clear enough to be called translucent. China is of a dead or bluish-white color, while porcelain is of a creamy-white tint. All our china is made from imported clay, and in the same way porcelain could be made, but it has not seemed profitable to introduce the manufacture up to this date.

There is only one establishment in Ohio where ornamental p alone is made, but the ornamentation of our best white-ware is very artistic and well done.

Stone-ware.

Stone-ware is first in simplicity and in order of establishment as well, and will therefore be first treated.

There are three stone-ware districts in Ohio; the largest at Akron, the most widely-spread at Roseville, Perry county, and the least important near Rock House, Hocking county. There are also a few scattered works in various parts of the State. The Rock House district uses the Mercer clay, as will be remembered, and supplies a large amount of ware to the neighborhood for twenty-five miles around, accessible to wagons only; no ware is shipped by rail.

The Roseville district is composed of a large number of small potteries; there are not less than eighty-five or ninety in the district, and most of them employ only a man and boy or two men, the largest employing seven men. The process of manufacture is essentially the same in all the districts, the main differences being those which naturally arise from the very different scales of working. The successive steps

are 1st, wetting the clay; 2d, grinding; 3d, wedging; 4th, turning; 5th, drying; 6th, slipping; 7th, burning; 8th, sorting the product.

In very many places the clay is put into a bin before using, and allowed to stand over night after drenching with water. This precaution is well taken, particularly in smaller works where horse-power only is used in grinding; in the largest steam works it is not necessary. The grinders for stone-ware clays are of several kinds; the simplest is a pug-mill, which is used in only one place visited. The next machine has no specific name, but is the one in use in all the country potteries. It is a square frame pivoted on an upright beam, which runs through the point of crossing of the diagonals, on the projecting ends of which are fastened cart-wheels, which work in a circular trough beneath. The whole frame revolves by the motion of a large cog-wheel above, which receives its power from the horse or engine; the motion is slow, but by weighting the corners of the frame, the wheels in their revolutions manage to cut the clay to pieces quite effectually. Such a machine, which can easily be made by any village mechanic, can grind from twelve to fifteen hundred pounds at a charge, and will occupy about two hours in doing it. This amount of clay will make from 180 to 190 gallons of ware. The clay, after grinding, is balled into large masses and "wet-blanketed" to keep until used. The grinding is done in the Akron district in steam mills called tracers, which will be further described under the head of the sewer-pipe manufacture. They are very efficient for stone-ware clays, grinding about 1,200 pounds to a charge in from 60 to 100 minutes. The clay being ground is put through a process called wedging; it is cut off in balls of 50 pounds or more, and cut by a wire into two parts; these are struck together in such a way that the two pieces unite different faces; the ball is worked up smooth again and is alternately divided and united by cutting halves and striking them together.

This treatment is supposed to eliminate blebs or spaces on the clay and any large pieces of foreign matter. When wedged, it is rolled up into wads or balls which have a definite weight for each kind of ware, and is then ready to be turned. The process of turning is too well known to require description.

The simplest work is making crocks and fruit jars, and after that come jugs, milk-pans, churns, etc. The range in size is from one pint to twenty-four gallons, though vessels holding forty gallons have been

made in a trial of skill on the part of the turner. As fast as the ware is made it is dried. In the country, this is done by setting a flat board covered with ware in the sun. In the smaller potteries of Akron and elsewhere, various devices are adopted. The ware is piled into a network of shelves under which pass steam-pipes. The largest and best stone-ware works dry it in closets, exactly like those used in the white-ware or china works, which will be noticed later.

The dry-ware is next "slipped". This technical expression of the potter designates the covering of the ware with any wash or solution. Applied to stone-ware, it means the washing of the ware in water containing a very fine-grained clay in suspension, so that its surface is covered by a film of clay. These slip clays on heating vitrify readily to a black glass, and run freely on the ware, making a very handsome glaze. The chemistry of the process is obvious. A partial analysis of theAlbany, N. Y., "slip," that is most largely used in the State, shows the following composition:

Sesquioxide of iron (Fe_2O_3)	1.43
Potash (K_2O)	3.17
Soda (Na_2O)	.74
	5.34

There is present besides a large amount of carbonates of lime and magnesia, which are undetermined. A clay full of the very finest silica and these impurities would, of course, fuse so readily that it would flow like a glaze at the vitrifying heat of stone-ware. Slip clay is found in various places in Ohio, but a great deal comes from outside points. Some of these clays fuse to a clear or nearly clear glass, in which case their fusibility is due to alkalies and earths alone. Some slips melt much easier than others, and potters have complained that their slip runs freely only at temperatures so high that the ware begins to lose shape. The judicious use of powdered feldspar, salt-water, or carbonates of soda or potash could easily correct this infusibility. The clear slips are best mixed with clays not readily fusible, but which are black in burning. The product has both color and fusibility. The composition of these clays may be farther illustrated by the following analysis of a "Kaolite" slip-clay, for which thanks are due to Messrs. Whitmore, Robinson & Co., of Akron, who use it in their works:

Silica ($Si\ O_2$)	62.40
Alumina ($Al_2\ O_3$)	10.42
Sesquioxide of iron ($Fe_2\ O_2$)	5.36
Lime ($Ca\ O$)	9.88
Magnesia ($Mg\ O$)	4.28
Alkalies (K. Na. Li.)	.87
Sulphuric acid ($H_2\ SO_4$)	.65
Phosphoric acid (PO_4)	0.19
Carbonic acid and water	8.05
	100.00

Probably not less than 45 per cent. of the silica present is a very fine-grained sand. The main trouble to be overcome in the use of slip glazes is a tendency to blister or "blubber." The cause of this is not definitely known. Every potter has his theory. The opinion of several of the most intelligent has been that undue haste in burning is the most frequent cause, and that the ware should be heated to a low red heat for several hours before any higher heat is attempted, after which rapid raising of the heat can do no harm. This treatment has certainly been successful under the conditions in which it was tested. When the ware is slipped, its capacity is usually stamped on it with a solution of smalt, or cobalt glass, which gives its customary blue color on heating.

The ware is next "set" in the kiln. The kilns in use vary considerably. The country kilns are usually small square structures, bound on the outside by logs of wood; the fire holes are left above the ground and communicate through the various arches of masonry which support the floor of the chamber above; this floor is full of holes, through which the fire freely passes, and the arched roof has usually seven vents of exit for gases. The chamber is oftenest about 8 ft. in diameter and 7 ft. high to the arch top. Such a chamber will hold, by nesting the ware, about 1,600 gallons. The firing is commenced at night, and is made very light indeed at first; in the morning the ware will be approximately dry, and the heat then continues from 20 to 30 hours, as the conditions vary. Nearly all stone-ware is salt-glazed on the outside and slipped inside. The salt is thrown in the fire when the heat is highest, and the vapors are seized by the clay and a soda silicate forms over the surface of the ware. The heat required to do this is the culminating point of the burning. The fuel is nearly always wood; coal is used in some places on a second fire-floor lower down than the one used for wood. This method of use will begin to grow as the wood

supply fails. The heat applied to stone-ware burning is rather severe, as there is always danger of not getting a uniform glaze in different parts of the kiln. The kilns in use at Akron for burning stone-ware are examples of the different scales on which the manufacture is conducted. They all hold 6,000 gallons, and many hold as much as 8,000. They are oblong kilns about 32x16 ft. and 12 ft. high; the fireplaces are at each end, and there are six of them; they are usually down draft with only one center flue; they are set and drawn from lateral doors, and require 70 hours to burn. A sample is usually withdrawn to test the efficiency of the glazing. Coal is in large use, though wood is still retained in small part. The cooling of a kiln should occupy as much time as the burning. The ware when drawn is piled in storehouses for shipment. In viewing a large amount of ware at once, of course the imperfections can be noticed more readily than one piece at a time. One of the most common troubles besides the "blubbering" of the slip, is the "pitting" of the ware in spots, due to iron. It is a peculiarity of stone-ware clay that while it needs iron to give it color, by far the largest part of the iron present is collected in grains and has no favorable effect on the color. These grains, if the heat is high enough to vitrify them, make pimples on the surface, or break out in rough spots which are black and ill-looking, from the silicate of iron formed. If the heat is too low to vitrify the grain, some change in its volume on heating causes a scale to separate from the surface of the ware, showing in the light colored cavity the piece of iron oxide at the bottom.

The failure of the ware to glaze is another source of trouble. This may be considered as due to ill-regulated burning usually, but one other cause is thought to act at times. Many clays exhibit collections of fine crystals of a whitish color, which prove on testing to be sulphate of lime or land plaster. This substance when exposed to vapors of salt at high heat, suffers a common chemical transformation and changes to chloride of lime, leaving the soda as a sulphate, which it appears either will not displace silica from combination, or will not do it at the temperature the ware will stand without losing shape, and hence there is no glaze. The heat, besides that necessary for the ware, must be high enough to make both slip and salt operate in glazing. The failure of the slip to melt leaves the ware of a rusty red color from the uncombined oxide of iron.

Stone-ware should exhibit, on fracture, a blue uniform tint, and a semivitrified appearance. Different clays act very differently in this respect.

Ware which does not vitrify can be picked out at a glance in most places. The Roseville clay, as a rule, vitrifies well. Its composition may be illustrated by the following examples:

	1.	2.	3.
Silica ($Si\,O_2$) (combined)	25.60	28.61	29.35
Alumina ($Al_2\,O_3$)	19.08	23.01	23.05
Water, combined ($H_2\,O$)	5.57	8.03	7.39
Sand (quartz) ($Si\,O_2$)	43.75	34.79	35.85
Titanic acid ($Ti\,O_2$)	.29	.35	.55
Sesquioxide of iron ($Fe_2\,O_3$)	1.26	1.50	.99
Lime ($Ca\,O$)	.60	.41	.58
Magnesia ($Mg\,O$)	.63	.62	.58
Potash ($K_2\,O$)	2.14	1.26	1.45
Soda and lithia ($Na_2\,O$ and $Li_2\,O$)	.02	trace	trace
Moisture	.94	.97	1.11
	99.86	100.57	100.90

1. Brummage's Pottery clay (Lower Kittanning), Roseville.
2. Allen's Pottery clay (Lower Kittanning), Roseville.
3. Uniontown Pottery clay, Uniontown.

The potash is well up in each, and the iron moderate; and in all, the per cent. of fine quartz sand is very large. This is imperative in a stone-ware clay. The clays of this district make a very good ware and differ from those of the Akron district, in that their final appearance is due to the proper chemical changes having occurred in the burning, while the other clay seems to burn naturally to a close uniform body without undergoing much real fretting or vitrification. Plenty of Akron-ware showing a good color and to all appearance vitrified, is of a yellow tint in the fracture. This ware is glazed of necessity, for it will not hold water when unglazed. Nevertheless the quality of these wares is excellent, and it is not at all certain that a superior degree of vitrification would improve it. Its composition is partially shown by these examples from Myers, Atchinson & Co.'s clay bank, at North Springfield:

	1.	2.	3.
Silica (total)	72.10	68.34	69.05
Alumina	19.38	22.61	21.37
Water, combined	5.13	5.56	6.00
Lime	1.38	1.99	1.70
Magnesia	.23	.11	.21
Moisture	1.12	1.00	1.00
Total	99.34	99.51	99.33

It is much to be regretted that time did not allow these analyses to be finished in the usual form, as from them it is probable that the peculiarities of the clay might have been explained.

The capacity of the Roseville district is not very large, yet most of the potteries can produce 1,300 gallons weekly, some less, and several more. Taking this as the average, 125,000 gallons weekly would represent the capacity of the district worked to full extent. By statistics, in 1882, this district is credited with the manufacture of 1,166,700 gallons, only about $\frac{1}{6}$ of its calculated capacity. The Akron district manufactured in the same time 3,337,500 gallons, which represents its capacity much more nearly, for the yearly output is that of a settled industry, while many of the small establishments of the former only work in those seasons when the farm labor is not in special demand.

The product of the rest of the State amounts to 86,000 gallons, and is distributed over four counties. The total value of product was $205,995, or 4.46c. per gallon. The markets represented by this product extend over the whole country. More perhaps goes to the south and west than elsewhere, but a great deal goes to home consumption. Cincinnati, Cleveland and Columbus are large markets. It has been shipped as far west as Denver, Col.

Earthen-ware.

The establishments devoted to this branch of pottery are small in number compared to the stone-ware works, but they are much larger in value of product.

Earthen-ware is made to include besides the red, porous, unglazed ware of which a flower-pot is an example, the yellow and Rockingham-wares of the market. The subject may be best treated in two parts. The manufacture of the commoner grades of earthen-ware is

not of great importance in the State. The clays used are quite similar to the stone-ware clays, but are less liable to semivitrification and fretting, and hold their iron in combination in that peculiar state which gives the brick-red color to a clay instead of the distribution of a small part, and the occurrence of the rest in small grains as seen in stone-ware clay. There are also some drift clays used for this work. The processes by which earthen-wares of this class are made are very simple. Materials like stone-ware, in shape and use, are fashioned mainly on a potter's wheel; flower-pots, etc., are made by similar means. The making of door-knobs forms an interesting phase of earthen-ware manufacture. The only two works in Ohio are in East Liverpool. The clays used are the native clays of that county, mainly from the Lower Kittanning horizon. There are two kinds used—a light clay, the same as the yellow-ware clay of this district, several grades of which are mixed to get a good body, and a clay obtained to the south-east of Liverpool, in the Barren Measures, probably, which is naturally red, and which burns to a cherry-red color. These clays, to be properly prepared, are put through a process called boiling. The clays are put into a vertical cylinder, about 6 feet in diameter, in the center of which revolves a rod carrying stirring and cutting arms, arranged spirally. This machine, filled with the requisite amounts of water and clay, is set in motion by horse-power; the clay is beaten to a thin mud or "slip". This is then run out in a fine stream, into a slightly inclined, oblong box, the bottom of which is covered by a fine bolting cloth. The sand, coarse grit, etc., is passed over the cloth and out at the end to a receptacle provided; the slip passes through into a large tank; from here it is dipped, as fast as needed, into a large iron-lined pan twenty feet long by five feet wide, and one foot deep. A fireplace and flues circulate underneath the pan, and evaporate the water from the slip. One panful a day (about 5 tons) is concentrated. When removed from the pan the clay is as soft and plastic as it is possible to be; it is piled up and covered with wet blankets to keep it tempered. Each color of clay is of course made separately. The clay, when ready to use, is next wedged. A block of both colors about 12″x12″x6″ is cut and sliced up by a wire into six or eight layers each; these are piled alternately into a new block one foot cube. This is lifted and thrown down with violence to consolidate the layers; it is then cut and welded again by a blow, and so on until the colors are marbled in fine alternating streaks. This clay is then molded into the requisite shapes, by first wadding with the hands

and then stamping in a die. The knobs are laid on trays in a steam-heated chamber to dry, and when hardened somewhat are put on an axis and turned to a smooth regular face. They are then dried thoroughly and burned.

The burning is done in saggers which are like those used for yellow-ware, to be described later, as also the kilns employed. They are piled in bulk for the first or biscuit burning. When burned they are dipped in a glaze. Its action is mainly due to lead, but it is slightly colored by iron. The ware is then piled in a sagger, separated by stilts, and is reburned. The finished products are then taken out of the kiln, are sorted and shipped in bulk, either by the thousand, barrel or even by the ton. There are two or three kinds of ware; some are wholly black and are called jets; the glaze used for these depends on manganese as a coloring agent. No white knobs are made.

These items were taken from the works of R. Thomas & Son, at Liverpool, where the industry may be seen at the best advantage. Nearly all of the product goes to several firms in the East engaged in making locks. The capacity is 15,000 knobs daily, requiring more than two tons of clay. The Knob Works of H. Brunt & Co. are developed on much the same scale and use both similar material and procesess. The modes of treatment used in other earthen-ware works do not need further description.

There are only two counties in the State where the productions have much value; they are Hamilton and Columbiana. In the former the work is mainly kitchen earthen-ware, in the latter, kitchen-ware and also door-knobs. The manufacture of yellow and Rockingham wares, included by definition in the class of earthen-ware, has attained considerable dimensions, and is the highest form of pottery for which Ohio deserves full credit, for the finer grades of ware, which are made from imported clays, are to be credited to the State only as proofs of manufacturing skill. In character, the clays necessary to make good yellow-ware are not separated from those used for stone-ware by any well defined line, though in general they are not quite similar in composition. In one instance the same clay is used for both yellow-ware, Rockingham and stone-ware in the same works, and by difference of process alone the product is made into a very good quality of either kind. This is done at the large works of Messrs. Whitmore, Robinson & Co., of Akron. But as a rule the clay should be less sandy, less liable to fret, nd the iron present should be in its well distributed shape.

The two districts for yellow and Rockingham wares are Columbiana and Hamilton counties. The former uses clays from the immediate neighborhood and has ten or more establishments. The clays are from the Lower Kittanning horizon and are mined by drifts. In East Liverpool there are nine large yellow-ware works, as follows:

Agner & Gaston	3 kilns.
S. & W. Baggott	2 "
Cartwright Bros	4 "
Croxall & Cartwright	4 "
Flentke & Harrison	3 "
Frederick, Shenkle, Allen & Co	3 "
McDeavitt & Moore	2 "
McNicol Burton & Co	3 "
C. C. Thompson & Co. (also make white-ware)	10 "

And at Wellsville are found the works of John Patterson & Co., four kilns.

The Cincinnati district has ten potteries, including all kinds of ware, white, yellow, Rockingham and earthen. The clays used here are all imported and come in part from Lawrence county, being the Kittanning clays and the Ferriferous limestone clays of that district. The other points where yellow-ware is made are few in number. Portage county is the largest center of production after the points named. The process is much the same in all the districts. It differs from stoneware processes in the superior skill and care used in all the steps, and is indistinguishable from the processes for white-ware or ironstone china except in the kinds of material and glazes used.

The clays as they are brought from the mines are allowed to slack in the air. No definite time is used in this process, as the clay is used as fast as needed, but a large enough pile is usually kept ahead to secure at least partial weathering. The clay is put through the process called washing, which is a common means of purifying all clays. The first step is mixing the clay into a thin slip, or as the potters call it, "dissolving" it, though it is only in a state of mechanical suspension and not in true solution. This is accomplished in what is termed a "blunger." It is a cylindrical vat varying from 4 to 6 ft. in diameter, in the center of which works a rod bearing arms suitably arranged to stir the clay up till it is all in a state of suspension. The slip is run out of the machine from a faucet, while still revolving, so that the clay will keep in suspension, into a bolting apparatus. This is a box slightly inclined with a fine bolting-cloth bottom. The slip runs through, leaving all

sand, grains of iron and other detrimental impurity. The slip runs into a large tank called the "agitator" in which it is kept slowly stirring by rotating arms, so that the slip is always of the same consistency, and no clay settles to the bottom. The bolting apparatus is worked by steam power and is usually vibrated by a cam and a spring. So far all washing processes agree, but beyond, there is a choice of methods. The slowest way is by boiling, as already described in the door-knob works. The more rapid is by pressing. The effect on the character of the clays is different in the two cases; boiling simply evaporates as steam all the water introduced, leaving any soluble alkaline or earthy matter behind, so that the effect of washing and boiling is simply mechanical, removing lumps and making the clay homogeneous and plastic. But by the other process the water is squeezed out of the clay by pressure, and as it goes, of course, the soluble matters go with it, and it would probably exercise some beneficial effect on a clay impregnated with the alkalies or alkaline earths. The action of the water might be made more marked in eliminating impurities by adding a small amount of some solvent suited to the case. If the alkalies are found in grains of feldspar or mica, or are present as soluble silicates, washing would eliminate them. Hence we can see the reason why yellow-ware and stone-ware both made from the same clay would not vitrify at equal heat. The presses used are all of the same style. They are frames of wood about 7 ft. long, 2 ft. high by 5 in. wide, standing on edge, about twenty to twenty-four of them in line; they are fitted to join together by lateral screw pressure into one long box. To each compartment is fitted a stout piece of duck or sail-cloth, which by proper folding acts as a closed bag, and from an orifice in the top of it it receives a stream of the fluid slip; the clay is retained in the bottom of the bag and the water runs out. The slip is supplied at a high pressure by a stout force pump; these bags become full of clay in time, and the water runs out through holes in the bottom of the box, coming out towards the end of the process nearly as clean as before use. The box, when full, is composed of parallel sections of clay of the size of the interior of the frame and separated from it and each other by the sail-cloth. When full, the water ceases to flow out at the bottom. The apparatus is taken apart, and the clay from each section rolled up in a wad, and carried away to a sweat-room to await use. The cloths can be used indefinitely. The capacity of the press varies with the number of chambers it has, and is about 100 pounds to a section,

making about a ton to an ordinary press. To fill a press requires about 45 minutes. The clay upon coming from the press is in a soft and plastic state, and is kept in a tight room or under blankets till used. The ware is burned in "saggers," or small clay receptacles, which are conveniently shaped to hold the ware, and thus protect it from the direct action of the fire; these saggers are in use in all potteries except those making stone-ware. They are made of the native clays for yellow-ware, but for white-ware they use a clay imported from New Jersey. The qualifications of a clay to make good saggers, are plasticity and refractoriness and an absence of a tendency to crack. If all of these, its success is assured; that is the reason why Ohio clays are not wholly used, because our Coal Measure clays, when plastic, are impure as a rule, and hard clays, though refractory, are not plastic. The saggers made from Ohio clays are in constant use at the yellow-ware works, however, and answer all purposes well. The old saggers, ground up fine, serve as non-shrinking material, and just as little green clay is used each time as will make the bond thorough and complete. The average life of a sagger is about 15 burnings. The stock of saggers necessary to be kept on hand is quite large, and it keeps several men busy in most works preparing them. The ware is put into them, but is supported on little triangular pins stuck in the side of the saggers so that it touches nothing but the knife edges it rests on. The manufacture of these pins and other devices of the same kind affords business to two firms in East Liverpool. The sagger is piled full of ware, all arranged so that the pieces do not touch the wall or each other; the top of the sagger is then luted with soft clay, and each successive sagger forms the roof of the one below, the clay making an air-tight joint. The kiln chamber is piled full of saggers, and luted shut, and the fire set. This is started slowly and raised steadily for 48 hours and cooled as long. When opened the saggers are removed, unpacked, and set aside to be inspected before they are used again. The clay itself, the qualities it needs to be valuable, have been noticed already. The excellent clay, used at Liverpool, shows on analysis:

Silica ($Si\,O_2$) (combined)	42.28
Alumina ($Al_2\,O_3$)	24.12
Water ($H_2\,O$) (combined)	7.77
Quartz ($Si\,O_2$) (free)	18.02
Titanic acid ($Ti\,O_2$)	1.20
Iron oxide ($Fe_2\,O_3$)	1 46

Lime ($Ca\ O$)	.59
Magnesia ($Mg\ O$)	.68
Potash ($K_2\ O$)	2.42
Soda and Lithia ($Na_2\ O + Li_2\ O$)	trace
Moisture ($H_2\ O$)	.86
	99.40

This analysis does not apply to the washed and strained clay. The sample analyzed was taken from the works of Frederick, Shenkle, Allen & Co., Liverpool.

The theory of the glazing of pottery is very simple, but in its application lies the excellence of one ware over another. There are certain substances that have the property of fusing under heat in the presence of free silica to a clear transparent silicate, of which glass is the type. To make a potters' product useful it must have its tendency to absorb liquids removed, which is done by wetting the biscuit-ware with a substance which will fuse to a clear glass with the silica of the clay, and give a smooth imperishable finish to the works.

There is a large range of bodies chosen to do this work, notably the alkalies, the earths, borax, lead, etc. The glazes applied to yellow-ware are usually made as follows: Proportions of litharge ($Pb\ O$), flint ($Si\ O_2$), spar (Potash or feldspar), Paris white ($Ca\ Co_3$), are mixed up in a grinding vat, with a thin slip of pure clay. This last is necessary to keep the heavier bodies from settling out; all the elements being well incorporated, the mixture is transferred to the glazing trough and used; heat of course on such a mixture, silica and lead, potash and lime with a little clay, would immediately produce a very fluid clear glass. Sometimes the carbonate of lead is used instead of the oxide, but the effect is the same. These are the main elements of a yellow-ware glaze; the special proportions used are kept secret by each potter, and even the constituents by many, though these may easily be determined by looking over the lists of bodies which would exercise the desired action. Each man believes his glaze better than his neighbor's, and he has been obliged to adopt its different proportions to suit the different qualities of the clay. Some glazes will crack over the surface of the ware and greatly disfigure it, and a change of proportion or working is necessary to correct this tendency. Rockingham-ware is the same as yellow, except in color; the addition of a large amount of manganese oxide is made to the ordinary glaze, and the ware first given

its ordinary glaze, and is then sprinkled or "spaddled" with the manganese glaze; this, on burning, colors the otherwise clear glaze to a beautiful brown, running to black. "Self-Rock" or brown-ware is made by the use of a manganese glaze over the whole surface, instead of sprinkling it. This outline was taken mainly at the works of Cartwright Bros., at Liverpool, where the industry can be seen at its best advantage, but visits to other works of the same sort have given additional range to the description.

The manufacture of earthen-wares in Ohio in 1882, according to available statistics, amount in value produced to $419,028.00, distributed in the main over 4 counties, but in a few isolated works beside.

White-ware or Iron-stone China.

This business is centered in two places in the State, East Liverpool and Cincinnati, but Liverpool has very much the greatest development. The manufacture of white-ware began in 1873, and was an outgrowth of the yellow-ware manufacture which had for years been carried on there in great quantity. The materials used are all imported into Ohio; the kaolin beds of Chester county, Pennsylvania, Maryland, Maine, Delaware, Indiana, Missouri, Virginia, South Carolina, are all represented, each establishment using from two to five kinds of clays. The ball clays used in the cheaper white-ware, or "C. C.," comes from New Jersey and Missouri. The saggers used in the white-ware manufacture are made from Woodbridge clay, New Jersey. The flint is made from the beautiful, clean white sand, which comes from the clay washings of Delaware. It is pulverized in a revolving barrel half-full of black flint pebbles. The spar comes from the quarries in Maine; it is calcined, broken up and ground in pans, the bottom of which are lined with French buhrstone, and on which revolve heavy pieces of buhr attached by chains to revolving arms. By this device, which bears a remarkable resemblance to the crude gold mills in use in Mexico, a very fine state of division is attained.

The main distinction between the yellow and white-ware manufacture is in the preparation of the clay "body". This "body" or mixture of clays, flint and spar, to be used in the molds, is the great secret of each establishment. Usually not more than one or two men in the works know it, and frequent transactions are made by which a recipe for a

body is sold for several thousand dollars. The clays chosen are selected with reference to plasticity, shrinkage, liability to crack, color, etc.; in a mixture, at least one light clay is employed, and the aim is to keep the mixture of clays as light in tint as may be and still secure the other qualities necessary. The flint is used in the finest state of division, and is perfectly white, as is the spar also. The body mixture of kaolins *alone* would, if heated, be liable to crack without apparent cause, and would be infusible at the heats applied.

By adding silica, which sometimes forms nearly one-half the mixture, the body is very much whitened, and the clay is much more like a stone-ware clay in composition, and is prepared to "fret" or vitrify on heating, but because of the purity of the reagents there is nothing present to cause vitrification with the free silica. Should this body be burned, all tendency to shrink or crack would be gone, but the bond would be very slight which would hold the mass together; a blow on a thin edge would give a dead, wooden sound, which well illustrates the lack of close union in the particles. By adding spar (which is powdered orthoclase, containing 14 per cent. potash) the mixture is complete; the color is corrected by the flint, as well as the tendency to shrink and crack, and with the presence of the spar the burning immediately causes a thorough vitrification of the whole mass to a homogeneous solid with a slightly glassy fracture. A blow on a piece of this mixture would give a clear, ringing sound, which also illustrates its state of combination. As there is necessarily some small amount of iron in the clays used, its yellow color is usually counteracted by the use of a very little cobalt. The blue and yellow colors really unite to produce a green, but this color has not nearly so strongly marked a character as either of its constituents, and escapes observation.

The glazes used in white-ware are much more complicated than for yellow-ware, and require perhaps the most skillful work of all to get just right; there is more value placed on the composition of a good glaze than any secret about a pottery, even including the composition of the body. The constituents and way of mixing an ordinary glaze are as follows: Proportions of borax or boracic acid, or both, with flint, spar, clay, and Paris-white are mixed while dry and put into a sagger, which has been previously coated with a wash of flint. This precaution is taken because the liquifying of the glaze would allow some of the iron from the sagger clay to color it if it were not protected by the pure

silica. On heating, the mixture becomes a clear glass, which is called "fret." This fret is ground up and mixed with fresh proportions of Paris-white, carbonate of lead, flint and spar, and is put into a grinding pan or vat lined with French buhrstone. In this it is ground up in a thin slip of pure, white clay, as something of this sort is necessary to incorporate the heavy parts of the mixture and keep them from setling out. This way seems a cumbrous programme to go through to get a liquid which shall vitrify the outside of a clay vessel, but the use of more direct agents, as the alkalies, is prohibited by the method of using it, which brings in the services of men whose hands and arms are in the glaze all day, which would be impossible if the glaze were alkaline. The most common difficulty met in glazing is the tendency of the polished surface of the ware to crack or "craze." This is due to a lack of adjustment between the coefficients of contraction of the body and glaze; and in the proper adjustment of this point lies the hardest problem of the potter.

Other troubles are also known; if a sagger leaks or admits air while hot, it causes the ruin of everything in it, for the sulphurous gases of the kiln immediately attack the hot lead silicate of the glaze, causing a sulphide film to form on it, which is black and unsightly. Even a piece of Rockingham ware shows immediately if air reached it while hot.

The grading of white-ware is made as follows: 1st, Ironstone china; 2nd, Majolica; 3rd, C. C. an abbreviation for cream-colored or for common clay, as variously explained, but in any case it is a cheaper grade of white-ware made from inferior clays. The distinction between china and majolica is much the same as that between yellow and Rockingham, a distinction of finish and glazing only; the body is the same. There is no reason why a C. C. ware should not be treated with a majolica glaze also, but so far it is not done.

The glazes used in majolica are applied, after the first or "body" glaze, in a soft, pasty state, and in dabs, which would presage a very rough appearance when finished; but on heating they melt and flow over the ware, making an effective play of color. The colors used are *in* the glaze, and differ from all other styles in being neither beneath or above it.

The decoration of pottery is a very large and complex subject. The theory of the art is not at all difficult to understand, but the longest experience is necessary to attain much real skill in its application.

The coloring agents employed in glass, pottery, enamels, etc., are

the metallic oxides, these being the only bodies whose coloring effects would last, at the temperature used. The color which each oxide produces are well known, but the proportions, manner of mixing and temperatures which limit its satisfactory effect are kept as trade secrets. The forms in which these oxides are used are called enamel paints, and are mixtures of the requisite oxide with suitable bases and fluxes, so that on heating the latter unite to form a glass which receives its color from the accompanying oxide. Almost any color may be produced by just such mixing, as the other branches of painting employ, but the greatest difficulty of the art is met in the adaptation of the fusing point of the glaze of the ware to that of the color. The oxides in commonest use are cobalt, blue; nickel, yellow or brown; iron, black; manganese, brown or violet; chromium, green; copper, red; tin, pink; tin and gold, purple; silver, or uranium, antimony and carbon, different yellows; zinc, opaque white; and gold, purple. There are several well-marked styles of pottery decoration now used, such as painting, striping and hand-painting.

The decoration of ware in Ohio embraces all these different plans, but in all cases the work is placed upon the already glazed ware. The development of this industry in Liverpool is enormous; a rough estimate has been made, that of the white-ware manufactured in the United States, Liverpool produces one-third, Trenton a half, and the scattered works one-sixth. The following firms are engaged in its manufacture at East Liverpool:

Wm. Flentke, white-ware	3	kilns.
Goodwin Bros., C. C. ware	6	"
Potters' Co-operative Co., white	4	"
Wm. Brunt & Co. "	4	"
Geo. Harker & Co. "	4	"
Knowles, Taylor & Knowles "	13	"
Homer Laughlin, "	5	"
C. C. Thompson & Co., C. C., white, yellow and Rock	10	"
Vodrey & Bro., white-ware	3	"
Wallace & Chetwyn, white-ware	3	"
Burford Bros., C. C. ware	2	"
West, Hardwick & Co. white-ware	3	"
John Wylie & Sons, "	3	"
Thirteen firms.	63	"

Besides these works, there are two stilt and pin factories depending on these for their custom, and a flint and spar mill, as well as two deco-

rating establishments for those firms who do not do their own painting. At Wellsville, four miles from Liverpool, there are two more white-ware potteries. The mammoth establishment of Knowles, Taylor & Knowles, manufactures at least twice as much white-ware as any two establishments in the United States. They employ over 500 men in their works, and there are nearly 700 men in their pay in the country. They use from 14 to 15 tons of clay daily, and turn out a crate of ware every ten minutes. Notwithstanding the enormous output, their work is as good as the English white-ware imported, which cannot be said of every American pottery.

The reason for this frequent inferiority is, that no science is employed in our potteries; no chemists are consulted; only the technical skill of the workmen has been exercised in production of ware, and it is greatly to our credit that the wares we produce take the rank they do; when English ware represents both science and technique as well, and ours means practical manipulation only. The value of wares produced in 1882 was $1,250,400.00, nearly $800,000.00 of which came from Liverpool.

The last subdivision of pottery which occurs is that kind which is manufactured for ornamental purposes alone. This branch, of course, does not need any extended treatment, inasmuch as there is but a single establishment in Ohio devoted to it. It will be treated on a subsequent page.

Refractory Material.

The art of making refractory material is already classed in the beginning of the section together with pottery, as the highest and most important branch of clay working. It well deserves this place, both by reason of the skill and science which may be applied to its prosecution, and by the important place that such materials take in many of our great industries.

The manufacture arose in Ohio gradually as an accompaniment of the iron industry, on which it depends for support. The first refractory material used in the State was sandstone, but as soon as stone-coal began to be used in blast furnaces the need of fire-brick was felt; its manufacture has progressed, following to some extent the motions of its first guide, until now it exceeds largely the demands of home consumption. Refractory materials may be classified as fire-stones and fire-clays. The

former are usually silicious rocks, but sometimes talcose slates or soapstones are used, which stand heat well in presence of basic slags. All firestones are used in the native state, and no other preparation than the necessary shaping. Fire-clay is the main refractory material, and is used only in the manufactured state. Its products are, 1st, brick ; 2nd, retorts ; 3rd, glass-pots ; 4th, linings and tile ; all of these are made in Ohio in large quantity and of unsurpassed quality.

Fire-Brick.

The fire-brick of Ohio are not as widely known or as highly esteemed as the Mt. Savage brick, for example, but they can do as good work and endure as severe tests as any made in America.

The processes by which fire-bricks are made are all quite similar, though there are several ways of accomplishing the same result, which are worthy of notice. As the grinding of the clay, to get the necessary uniformity and fineness, is the most important step in any clay process, it is in accomplishing this point that the differences in process are found. The necessary steps in making fire-brick are as follows: 1st, mixing clays; 2nd, washing; 3rd, grinding and tempering; 4th, molding; 5th, drying and pressing; 6, burning; 7, sorting the product.

The first step, that of mixing the proportions of the clays used, is the part in which the skill of one operator over another is manifested. The discussion of the proper mixtures to produce certain effects will be taken up to greater profit after the process has been described, but the mechanical part of the work may here be spoken of. The proportions of flint, calcined and plastic clays which shall compose the brick, having been determined, it is the duty of certain men to prepare these charges for grinding. The piles of clay from which the selection of clays is made, usually adjoins the works as closely as possible, on the side next to the grinding machinery. In many places the amount kept on hand is large, amounting to 7,000 or 8,000 tons. There is no object in thus storing clay, unless it be either to insure a supply for some time in advance and guard against transient interruptions, or to allow the clay to slack and break up fine, thus omitting part of the mechanical preparations otherwise needed. There is a belief largely current, that allowing a clay to weather acts advantageously in ridding it of impurities. Though it cannot be denied that under certain conditions this would be so, yet it is equally certain that these influences are much overrated.

The impurities which would thus escape are potash and soda, from such compounds as feldspar and mica; yet the decomposition of these minerals having been effected by weathering, the mechanical conditions which would aid in the escape of the impurities are seldom found. A strong slant to the floor of the clay pile, so that water would drain away quickly and well after raining, and only a thin layer of clay on the floor so that impurities from the top layers might not lodge in the bottom, would favor the escape of impurities, but the exact opposite of both of these conditions as a rule prevails. Iron sulphide and carbonates of lime and magnesia would also tend to decompose and leave the clay, but their action would be very gradual. But the mechanical subdivison of the clay which takes place is undoubtedly advantageous; alternate frost and heat has long been reckoned as a valuable agent in increasing the plasticity of hard clays. From the pile the materials are selected; the mixture of so much of each factor is made by counting the shovelsful with which the charging barrow is loaded. In no case in the State are the constituents weighed; no closer proportion is kept anywhere than careful shoveling will make. The barrow being loaded, the clay should be washed; in only one place in Ohio is this precaution taken. That is at the works of the Portsmouth Fire-brick Co. The washing there is accomplished by running the barrow over a sink or drain and drenching from a hose above. The barrow being perforated on the bottom speedily drains dry again. This treatment, though not thorough, tends to free the clay from dust, mud and dirt which stick to it from the diggings. The best method of washing seen was at the excellent works of Harbison and Walker, Pittsburgh. Their machine consists of a cylinder, revolving in a slightly inclined position in a trough of water. The wall of the cylinder is made of coarse iron gauze or netting, and on the inside is bolted a spiral flange beginning on the upper end and running to the other extreme. A charge of clay is introduced into a hopper at the upper end, and by the flange is slowly carried down the length of the cylinder, being agitated in water, which is about 6 inches deep in the lower part of the cylinder. This machine is only used to wash hard, uncalcined clays, for the plastic grades would not stand so severe a treatment, and calcined clays do not need it. Washing is only useful or advisable where the hard clays in use are mined by benching or stripping and comes to the works covered with mud or dirt.

The next step is grinding the charge; as before stated, this is the

most important step in the process, and consequently the one in which the most variations are found. The different methods adopted are: 1st, the wet pan process; 2nd, the dry pan and pug mill; and 3rd, the dry pan and wet pan mixer. The use of these different kinds of tempering mills is not really restricted to any one kind of clay, though the use of each kind is widest in certain districts of comparatively uniform grades of clays.

The wet pan process partially explains itself by its name. The clay is introduced into a large circular iron pan, which revolves continuously on an upright axis. In the pan, and fixed on a horizontal axis, are two very large cast-iron wheels; as the pan revolves, the wheels are also turned by the friction between their circumference and the pan floor. The axis on which they rest is commonly made of two cast iron sections which are made to fork at the bolting ends and inclose the vertical axis of the pan. The hole thus made in the horizontal axis is at least 2 inches larger in diameter than the upright axis, so that the shaking of the machine does not cause friction. The ends of the horizontal axis are fixed in slots in the timbers at the sides of the mill, so that when a charge is newly put in, the wheels have the chance to run *over* large lumps of hard matter, rather than being compelled to crush them at the first trial or break.

These wheels are from 24 inches to 42 inches in diameter, from 8 inches to 14 inches in width, and weigh from 3,500 pounds upwards; the average of the wheels from twelve of the best works in the State is 4,400 pounds, and the highest weights used are 5,600 pounds. The pan itself is cast in one piece; it is 7 feet in diameter, and about 1 foot deep; it is provided with a false floor which can be renewed at any time, so that the real pan floor lasts indefinitely. Motion is given to the pan by a strong system of gearing; appropriate guides are used to keep the clay under the wheels and keep it well stirred up. As a charge is dumped into the machine, the lumps cause the wheels to jump up and down with some vigor, but a few revolutions serve to reduce the clay to a finer state, and only a short time elapses until the material forms a homogeneous paste. The grinding lasts from 7 to 15 minutes, as the wheels vary in size and the clays work easily or not. In this period the plastic clays are in a state of complete disorganization and are spread as a bond between the coarser particles of flint and calcine. The

clay is tempered to the right consistency by additions of water. The pan is usually fitted with a pipe from the engine from which water can be had by turning a faucet. Either hot or cold water may be used; it probably makes no difference which, in the quality of the brick, but the former makes the work of the molder much more endurable.

This machine is found in widest use, where a hard, flinty clay and considerable calcine is used. In charges containing considerable amounts of both these bodies and only a little plastic clay, such hard and intimate mixing is the only way in which the structure of the brick can be made sound. This wet pan process is used entirely in the Sciotoville district, Ironton and Logan, and from this part of the State much of the finest brick comes.

The dry pan and pug mill mixer is the style of grinding least adapted to general use of all three ways, but is a cheap and useful method in some cases. The pan is very similar to the ordinary wet pan, but has this difference: the floor is fitted with plates cast in segments fitting on a framework of radii beneath the pan. The plates are thus fitted into a level and continous floor; they are full of parallel slots or holes, which open immediately into a larger room from the underside, so that any particle of matter which passes the surface will have no chance to stick lower down. Beneath the pan is a bin into which the clay, as fast as it is reduced fine enough to pass the bottom of the pan, falls; in this bin revolve arms, which collect continually the powder and deliver it at the foot of an elevating belt which is at one corner of the bin. The charge is all introduced together and is run until it has all disappeared beneath the surface, or else its proportions of calcine would not be equally distributed. All dry pans are subjected to this disadvantage, that the softest parts go through first and the harder last, so that the powdered clay, as delivered by the elevating belt would not be strictly homogeneous; also the largest part of the clay goes through at once, and the longest part of the grind is devoted to getting the least of the charge through, which is a waste of energy. Another disadvantage resulting from this pan is the fact that the hard material is never rendered finer than is necessary to pass the holes in the floor, which to make the machine work at all rapidly are necessarily larger than is good for the brick. The powdered clay having been delivered into a bin above, is ready to be mixed as needed. The mixing machine is a trough about 18 inches wide by 8 feet long by 18 inches deep; in it works a horizontal

axis on which are fixed cutting arms which are arranged spirally, but at such a pitch that their action is slow in moving the clay forward. The tempering is done by merely adding clay and water, and allowing the machine to mix it up to a paste. It is mixed and quite thoroughly incorporated by the time it has worked the length of the trough, and it is then squeezed out upon the molding table.

This process is one simply of mixing; no element of grinding enters into it. It is not popular among clay workers, and is only applicable to certain kinds of clays; those best suited are plastic clays, or mixtures of plastic clays, or at any rate mixtures involving but little flint and calcine. There is no particular district covered by this kind of a mixer, but in every district it is in some small use.

The third method is the theoretically correct one of all in use, but it is the most expensive of all as well. The dry mill used is exactly like that before described, and is adjusted to deliver the ground clay as before into an elevator. This carries it up to the top of the building and delivers it upon a screen. This screen is a box about 14 feet long, by 4 wide, by 7 feet deep; the bottom of this box is made of sheets of perforated sheet-iron, the holes about $\frac{1}{10}$-in. in diameter; the slant is about 45°, so that whatever enters the screen is sure to leave it either by passing through or by running off at the end. That which escapes from the end is carried down by spouts to the dry mill and is re-ground, so that a charge being introduced runs on until it is all through the sieve. That which passes the sieve is caught by a cloth or board hopper beneath, and is conducted to the tempering mill or to the bins for storing. The clay which has been screened is beautifully fine and even. The tempering mill is on the same principle as the wet mill first described, but is of a larger diameter; the wheels are arranged to turn instead of the pan frequently; they are of larger diameter and less thickness than the wet pan wheels, and weigh usually 1,800 pounds each. The pan is provided with water and a charge is thrown in wet and ground briskly until as plastic as can be; by this course of treatment, the qualities of the clay are developed to the best possible effect. This process is in favor in all the river works of Jefferson county, and at Mineral Point, and Haydenville, besides. Along the river, the clays used are as hard and rocky as sandstone when they are newly mined; they are sandy and apparently non-plastic, but by this treatment develop into one of the best working clays in the State.

The details of these processes are all interchangeable, and various combinations of these different machines are seen. The older machine used for this purpose was the Cornish roller, which may still be seen in a dismantled condition around some works. Tempering is always tested by the sense of feeling, and the workmen become very skillful in telling the degree of moistening necessary.

The grinding once accomplised, the steps which the plastic, tempered clay is put through are much the same everywhere. Molding is the next operation to be performed. This is done either by hand or machine; the latter is only used in three or four places in the State for making fire-brick, and indeed its use for making common brick is not much wider. The process of hand-molding is very simple; and does not need description.

The machine molders employed in Ohio are two, the Martin press and the Baker press. They are essentially the same thing, only differing in some technical points. The plan of their action is as follows: In a vertical box, three feet square, works a pug mill just such as is used in the horizontal trough of the dry pan process; the clay is fed at the top; as it reaches the bottom of the chamber, the last arm of the pug mill is so shaped and so pitched as to expel a large wad of clay at each revolution. This mass is forced forward and downward so that it partially fills and wholly covers a mold with five chambers. A vertical eccentric from above works a vertical plunger up and down, which forces the clay into the mold and packs it tight. Its motion is so timed that the pug no sooner pushes the clay over the mold than it is driven home by the plunger. Another piston, working from in rear, pushes out the mold full of brick to the front and supplies a fresh mold. The full mold is stroked off with a flat board, and is carried away to be dried. The machines are designed to temper the clay and mold it as well, but this treatment is not found practicable in making fire-brick, as the material needs a longer preparation. This preparation consists, in one of the works where machines are used, of a dry mill with screens and a pug mill mixer which delivers directly into the press top, making a very efficient mixing process. The capacity of these machines is large, varying from 20,000 to 25,000 brick a day, as variously estimated, but in no case is their capacity put to the test in fire-brick making, as the room and other plant needed to justify such an output is nowhere found.

The men employed on one machine are six—1 man to temper the clay,

1 to stroke, one to sand and place the molds, two to carry off, and one odd man. Making 12,000 brick a day, or half the capacity of the machine, these six men do the work of three molders, six off-bearers and one or two odd hands. The products are well-shaped brick, with square edges and corners, but are always rough on one side where they were stroked. A machine-made brick can usually be distinguished by this peculiarity. The work done on the whole is *good* for brick to be used in second class work, such as boiler settings, flue linings etc., as all machine-made brick are, because they all use plastic clays. The cost of the machine and its running power are both small.

The molding done, the pressing and drying are next in order. The drying of hand-made brick may be done in two ways—by hot air or by a hot floor; the latter is much the more important and common in its use. One of the principal features of a fire-brick works is the drying floor.

Some of the best examples in use are built as follows: Across the end of the floor, which is nearly always rectangular, is dug a pit some six feet below the general level. In the wall of this pit are set fireplaces at intervals of from 5 to 6 ft. These fireplaces proceed inward about a yard, and then break up into from three to five parallel flues. These flues are about 10 inches square, and are separated by 4 inches of brick. The flues traverse the whole distance of the floor and unite in a chimney or chimneys at the other end, which must be high enough to make every individual flue draw. These flues are covered by square tile 12 inches on a side; they are placed 4 thick at the fire end of the flue, and run down to 1 at the opposite end. This is done to equalize the heat of the floor. The depth of the flues is so arranged that their unequal covering brings the tile to a level plane; on this is spread a cement adapted to this use; it is made of basic furnace cinder and sandy clay in equal parts, ground fine, and wet. If the cinder is not basic enough, lime is added; the mixture sets very hard and will last four or five years if well treated. Sometimes the flues are covered with one thickness of tile all over, and are then leveled up with sand and another layer of tile. This is undoubtedly cheaper, and is also as even a distributer of heat as a plain tile floor would be, but is rather more apt to cause trouble in repairing by blocking up the flues with sand. The custom is to keep the floors hot constantly; the mass of the body heated makes this easy to be done. The fuel used is coal slack in almost all cases, as its com-

bustion is gradual, and after the floor is once hot, gradual heat is the kind wanted. Bricks placed on such a floor dry in 24 hours from the tempered, plastic clay, to a state so hard that the hand can make no impression on them. When the bricks are about half dry they are pressed and again dried. The size of the drying floors used is very various, and is an index of the capacity of the works. At the works of the Scioto Fire Brick Co., at Sciotoville, the fine new floor recently put in is just 100 feet square and heated by 24 fireplaces and about 80 flues. Several establishments have floors 160x80 and 120x60. Lack of drying floor constitutes one of the greatest obstacles to an increase of capacity of a factory. Air-drying is usually done in the second story over the ordinary drying floor. If the roof be tight the heat in the second story is quite uniform, and is strong enough to do quite rapid work. The temperature is often 100° or 120° naturally, and by using a slat work floor the capacity is largely increased. The kinds of ware adapted to an air-drying are large pieces which the heat of a floor can only attack on one side at a time, which is always done at a risk of cracking.

The drying of machine-made brick is usually an air-drying process, but at the ordinary teperatures of the outside air as found under open sheds, though sometimes a plant is arranged inside the building. The drying of the brick is interrupted about half way through by the pressing. All hand-made brick, except the coarsest grades, are pressed. Machine-made brick never are. The pressing of the brick is done by a gang of workmen either four or five in number. The work of a press-gang is the same as the molding-gang, and is about 4,000 brick a day. The presses most widely used are those made by F. C. & D. R. Carnell, of Philadelphia; the other press in use is that of S. P. Miller & Son, also of Philadelphia. They are both the same in principle, though different in detail. The pressing of the brick is done in a steel, brass-lined chamber with a sliding top, and a bottom which has the freedom to move up or down. By a strong application of lever power, the bottom is moved up, and the brick smoothed up into a compact, well-shaped body. The brand is usually put on the bottom plate of the press, and is thus impressed on the bottom of the brick as well.

The pressure obtainable on such a press is not known to those who use them, if it is to those who make them, but it is ample for all purposes. There is little gain in subjecting a brick to powerful pressure; it possibly increases its infusibility a trifle, but the effect is not perceptible

as a rule. The molds used on the presses are changed with ease, and a set is usually kept, including all kinds of arch and key-brick, together with special shapes. Any special design can be speedily made to order also. These machines are also made in larger sizes to press such wares as furnace blocks, but they are not in common use. The sixth step in the fire-brick process is the most interesting of all; it is the burning of the ware, now dried and pressed. This part of the work calls for more technical skill than any other portion. The considerations to be noticed in this connection are, first, the kiln; second, the manner of drawing and setting; and lastly, the points observed in the chemistry of the process.

The different kinds of kilns used in fire-brick manufacture can only be touched upon here. They may be classified as:

Kilns.—	Up draught —	Without roof—	Fired at side	1
		With roof—	Fired at side	2
			Fired at end	3
	Down draught—	Circular		4
		Rectangular	Fired at side	5
			Fired at end	6

All of these are found in Ohio, with several other forms differing from these types by small features, but the three kilns in wide use are Nos. 1, 4, and 6.

The first and simplest kiln employed in fire-brick manufacture is the rectangular, up-draft kiln without any roof. Its use is still very large and it suffices to burn much of the best brick in the State. It consists of four walls of common fire-brick, from 18 to 24 inches thick, lined with the best grades, and built on firm stone foundations. The side walls are perforated by the openings of the fireplaces from outside, and the ends are provided with doors through which the kiln is set and drawn. The fireplaces are built either separate or in one continuous block. They are small covered chambers, running direct back into the kiln; the grates are set in a standing position so that the whole aperture can be filled with fire during the culmination of a hard burning. The dimensions of this style of kiln vary from 10 to 14 feet wide, 11 to 12 feet high, 25 to 40 feet long, and from 50,000 to 75,000 bricks capacity. The burning varies with the hardness desired, character of brick and fuel, etc., from five to eight days; perhaps six days is the most usual time. The brick cool from two to four days, according to the need in which they are held. These kilns are used in the whole Sciotoville

district, at Ironton, Logan, Akron, Cleveland and Zanesville. The next kiln in wide use is the circular down-draft. It is largely used for brick and still more largely for pipe, etc. It varies from 16 to 24 feet in diameter, with from 18 inches to 24-inch walls of the best fire-brick and with strong iron binding. It is from 10 to 14 feet high to the top of the arched roof. The fireplaces are arranged around the base of the kiln each one separate, usually, but sometimes in a continuous block. They pass into the kiln and are deflected upward by a so-called fire-wall, which is a partition concentric to the outer wall of the kiln, about 10 inches from it, and extending upwards to the spring of the arch. This wall is of the best quality of brick, as it has to stand the severest heat attainable in the kiln. The fires being turned up between these two walls first reach the brick from above over the top of the inner wall. The draft now sucks the fire down through the bricks piled in open order, through the floor, which is built of perforated brick, into the flues beneath, which run into the base of a large stack. The whole draft of a kiln may be stopped or retarded at will by blocking up the flue to the chimney, and these kilns owe their value over the up-draft kiln mainly to the ease with which they can be regulated. Burning takes a little longer, perhaps, than with an up-draft kiln, but the down-draft is more economical of fuel. These kilns do not attain such high heat, and consequently the brick are usually softer burned, but are rather more uniform. At the works of C. E. Holden, Mineral Point, there are three large circular down-draft kilns whose tops are connected each to the other by a boiler-iron tube about 1 foot in diameter. When one kiln is hot and cooling, and another is just set with fresh brick, the flue to the stack from the hot kiln may be stopped, and the current of hot air directed through the second kiln and out of the stack, thus performing rapidly, uniformly and completely all that sweat-burn of a kiln usually does. By this means a fire is not let into the kiln until all is ready to raise the heat at once to a high point. Any of the kilns can thus be manipulated, being cut out or brought into the current by a movement of damper.

The use of a real fire-wall is not as common in circular down-draft kilns as in rectangular; the same effect is obtained by inclosing the vent to each fireplace in a chimney which runs up the wall to the usual height, and delivers into the ware just as a fire-wall would. These chimneys are called pockets.

The rectangular, down-draft, end-fired kiln is in common use in

the Akron district and in a few of the river works. There are usually 3 fires to each end; a fire-wall is used instead of pockets, and the down-draft finds exit through a central row of perforations to the flue beneath. The draft has a little tendency to strike straight from the fire-wall to the flue in the floor, but by judicious piling the draft can be entirely controlled.

The refractory property of clay can be studied to no better advantage in any way than in the compounding and burning of fire-brick. As the work is done at present, no great knowledge of the theory of the subject is required, but there is room for great improvement in its scientific treatment.

The problem of making a refractory brick from native clays is based upon the fact, "the purer the clay the more infusible." Our purest clays are our flint clays, which are probably refractory by reason of their structures, as well as their composition. These then make an admirable basis for the brick. As they are non-plastic, their successful use compels the addition of a small amount of plastic clay, and on the choice of this clay all depends. A fine-grained, sandy clay hard in its native state, and plastic when ground up in water, makes the best bond; it is needless to add it should be pure. The more aluminous a clay is the more it will shrink on burning, and if the clay which has been used to incorporate the non-plastic part should shrink materially on burning, it would loosen the bond between the pieces of hard clay and make the whole fabric unsound. Therefore the clay fit for a bond is one in which the natural shrinkage is at a mininum; this condition is found in a fine-grained sandy clay. It is ignorance of this point, which seems so simple, that has caused the failure of so many patent mixtures for refractory materials. It has seemed to each man in succession, who has approached the subject, that as pure kaolin is infusible, and pure sand is infusible, and as these bodies represent respectively our ideal of plasticity and non-shrinking qualities, a proper mixture of the two should produce the most desirable results. But, when such a mixture is heated, the enormous shrinkage of the kaolin loosens the bond of the whole body and makes it weak and fragile. For the clear statement of this point, thanks are due to Hon. J. Park Alexander, of Akron, who has experimented widely on the compounding of refractory mixtures.

If, then, a pure, sandy and plastic clay can be found, the bond is one likely to be satisfactory; but the main trouble is in a lack of purity, for

if a clay fills the other conditions required, it is liable to be impure like a stone-ware clay.

There are three grades of fire-brick which can be recognized. The first or No. 1 brick is the best and most refractory, and is intended for the severest use, such as the hearth and boshes of the blast furnaces, the exposed parts of puddling furnaces and steel-mill plants. Its application enforces the use of a very large proportion of calcined and flint clays with the least possible plastic clay which will bind them together. In several places the mixture is composed of about half and half of each of these with no plastic, and the mixture is ground very severely in a heavy wet mill for a long time.

It is claimed by the makers of this class of brick that any flint clay, being reduced to a fine enough state of division, under violent friction, will become plastic, and it is certain that the clays which they use do so, but is still an open question if all flint clays will. The more usual charge for a No. 1 brick consists of about 45 per cent. of both flint and calcine and 10 per cent. plastic.

The cohesion among the particles of such a mixture is very slight, and very light friction suffices to shell the brick up into its component parts; it is of course unfitted for use in any position when friction will be brought to bear, but at the intense heat at which they are used, the softening of the clay makes them as cohesive as need be, and in that state the friction of matter as highly heated as the brick has but little effect.

The next well-marked grade of brick has neither name nor number among its makers. It is composed of about equal amounts of both flint and calcine, and about three times as much plastic as the No. 1 brick.

Its proper uses are the same general kind as those for the No. 1 brick, but the product is a little inferior to it. The next grade, or No. 2 brick, is made of about 50 per cent. of plastic, 20 per cent. calcine and 30 per cent. flint clay; it has a homogeneous appearance on its fracture, is close-grained and emits a sharp ring when struck with another brick. Such a brick will sometimes stand a very fair heat with no symptons of fusing, but, as a rule, it is not fitted for any responsible position. It is excellent material from which to make kilns, etc., except the hottest parts. What might be denominated a No. 3 brick consists of a mixture of several plastic clays, or else a body made of one plastic grade. They are generally vitrified slightly in the burning heat of a

kiln, and precaution must be taken to keep them from sticking together. They are excellent for making flues, pavements, boiler settings, chimneys, etc., and as they can be well made by a machine they ought to be furnished at low rates. The burning of these various grades of brick demands considerable technical skill. The products exhibit many phenomena which are very interesting; iron, in particular, is noticed in the black blotches which its union with silica has caused.

Often a nail, bolt or some stray piece of iron gets into a kiln of brick. Its effects can be seen in a large, conical hole in the brick lined with the black cinder of iron and extending downward as far as the iron lasted. The blackening of the faces of the arch brick and those most exposed to the direct heat of the fires has often been mentioned by brick men as being the result of impure fuel and sulphur in the coal. This explanation is incorrect; sulphur, i. e., sulphide of iron, when burnt in a grate would decompose to SO_2 or sulphurous anhydride, and in that state would pass into the kiln. The only effect the gas could possibly have on hot silicate of alumnia or any body likely to be present in clay would be to recombine in the same state from which it has just been expelled by a less heat than is met in the inside of the kiln. The true explanation is this: the heat on the brick that are blackened is more intense than on any other part of the kiln, and they are rendered softer and nearer to fusion; while in this pliable state, the draft from the fires just outside carries in a very appreciable amount of dust and ashes which lodge on these portions and flux outside to the black crust seen. The burning of terra cotta in the Ohio Valley gives some interesting points in proof of this view.

Among other grades of brick made are several patent mixtures and various secret compositions called "silica" bricks, etc. Noticeable amongst them is the patent brick, made by Mr. J. Park Alexander, of Akron, which is used in the roofs of reverberatory furnaces and in steel works. The brick is made of a peculiar form of silica cemented by caustic lime. The bricks are very delicate, and are easily crushed by the hand, but once in place they are considered a very superior article. The great preponderance of silica in their composition, makes them expand under heat instead of contracting, as a pure clay does, so that when built in an arch so flat that there is trouble in keeping it up, the heat of burning causes the arch to bow upward from the expansion instead of sinking in as it would if the brick contracted.

One of the troubles of a clay brick, which a silica brick escapes, is its so called "dropping" when placed in the roof. This means either of two things—1st, that a crack has formed across the brick which leaves a piece free enough to fall when any change of temperature loosens it—this is the peculiar property of a pure clay; and 2nd, the formation of a crust of fused clay and ashes on the surface which cracks off and falls when the brick cools.

Besides the Alexander silica brick, there are several other styles in use: the N. C. (Niles composition), made by the Thomas Brick Works, at Niles, is one of the prominent ones. In this a conglomerate sand-rock furnishes the silica which is used with a clay bond. No bricks of this highly silicious character, approximating in value the celebrated "Dinas" brick, are made in the country.

Nearly every kind of brick in the market comes from some one district in excess of any other; the No. 1 bricks are mainly made in the Portsmouth district, with isolated establishments at Logan, Columbus, Mineral Point and Cleveland. No. 2 and No. 3 grades come from the Ohio Valley Works.

Besides the manufacture of bricks alone, these same establishments also turn out many other kinds of ware, notably furnace blocks, glass-house eyes and special pieces made to order. These are made just as brick, after once deciding the composition to use, except that some extra hand labor is employed to make a nicely-shaped product.

Retorts.

The manufacture of clay retorts for making gas is now carried on quite largely, and the product is fast replacing the iron ones which were formerly used. These are made in two places in the State, the first and largest at the works of the Cincinnati Fire Clay Retort Co., and the second at the Dover Fire Brick Co.'s establishment.

The clay body is compounded to stand considerable heat without any tendency to soften, for so large a piece of hollow-ware must be refractory to maintain even its own weight at the temperature used. The mixture requires more care in compounding than a brick mixture, for more is involved in the failure of the retort to do good service than a few bricks. Calcine is used in large amount, but crushed rather finer than common, and it needs a very good and plastic bond clay.

The retort is shaped from the tempered clay by filling the space

between a large sheet-iron shell and a wooden core. The shell is placed in position and the floor covered with clay 4 inches deep and tamped. The core is then introduced and adjusted so that 4 inches separate it from the walls on all sides. The clay is filled in small amounts at a time and tamped gently. When the retort is high enough the core is withdrawn by a crane and the mouth of the retort built by hand. The shell is then unbolted and removed in two pieces, and the finished retort is standing on its end. It is left to dry for several weeks in this position and is finally removed to the kiln to be burnt. It is put into an ordinary fire-brick kiln, and brick are piled around it to keep it in position without sagging. These retorts are cheap compared to the iron ones, and where in steady use and never allowed to cool they prove very durable.

Glass Pots.

The third class of refractory material consists of the large pots in which glass is melted and worked. They are made by one large establishment devoted to that specialty and by several of the glass-houses using them in the large way.

The establishment referred to above is the Ohio Valley Pot Clay Co., of Steubenville, of which Mr. S. Brown is the superintendent. The clays used are, 1st, Gros Almerode, near Coblentz, Germany, for bond clay; 2nd, Christy clay, from near St. Louis, Mo., used for calcine and bond; 3rd, Blue Ridge, Missouri, clay, used for bond and calcine; 4th, Mineral Point, Ohio, flint clay, used as flint and calcine; 5th, old pot shells for calcine.

The German clay is shipped as ballast in the holds of vessels and hence transportation costs but little, much less than the Missouri clays in fact. It is an excessively fine-grained and heavy clay, and is very plastic, making a better bond than any native clay. It comes in blocks 9″x6″x6″, which have to be pared with a draw-knife, and then broken and inspected and all irony spots removed. No pieces larger than a walnut are allowed to go into the mixture. The work involved in getting the clay ready for use is excessive, and it is the opinion of those at the works that it is much overrated. It is an excellent bond clay, it is true, but its refractory properties are excelled by the Christy clay of Missouri.

These Missouri clays come in blocks, either calcined or raw. They

are pared and broken but not sorted over. They are washed before shipping, so that they are much finer than in nature. The Blue Ridge is the finer-grained of the two. The Mineral Point calcined clay is not now largely used, because the extensive connection of the company allow them to get back their old potshells for calcine, which, being already in the desired composition of the mixture, make a better calcine than any single clay.

These shells are chipped with small hammers until no part of the surface remains and only the clean interior is left. The charge is composed quite largely of calcine with a little flint clay, and the remainder German and Missouri bond-clays. The mixture is ground in a dry pan and sifted by a jig bolt, and the coarse part re-ground. It is then pugged five or six times in succession and then is stored and blanketed. It remains in this state until it sours and smells offensively, which the men claim is necessary to its proper working. It is wedged by hand and is ready for use. The pots are large structures about 5 feet high, 4 feet wide and 4 feet long, bounded on top and sides by covered walls, and on the bottom by a flat face. They weigh from 2,000 to 3,000 pounds, and sometimes as much as 3,500 pounds. They are made from 3 to 5 inches thick with a thicker floor, and are each built on a small platform covered with gravel, so that air may circulate beneath them and dry them faster. They are built entirely by hand, small pieces being added daily, and left to harden before another addition is made. Each builder, of which there are four, has on hand 12 or 15 pots at once, on which he daily builds a little more, until at the end of three weeks or a month he finishes them all together. Thus about 60 pots a month is found to be the average turnout of the works. The building is a large four-story, provided with elevators so that the heavy pots can be handled without danger of hurting them. They are dried from one to six months, and the longer the better, and are shipped on three-wheeled trucks, which are returned to the works, so that they are loaded and unloaded with ease and security, where before there was always great danger of breaking them. Each pot is worth from $60 to $75. The quality of the ware made at these works is excellent, and has a wide circulation amongst glass workers. The works are under most intelligent supervision, and the process would furnish material for a much fuller description if space allowed.

Linings and Tile.

Besides the well-defined classes of refractory material which have been described there comes a last division which has no such clear definition, but which nevertheless needs some mention.

Nearly all metallurgical industries have some special device which has to be made to order. They generally furnish a model to some brick factory, and let them furnish them with their whole supply. Also such work as making the different kinds of stove linings, and house-furnaces and grates, and a long list of similar necessities, engages the attention of several companies. There is little to describe about their manufacture—they do not require any great care of composition, and more hand-labor is employed to give a nice finish, but in all other respects they fall under previous descriptions.

The number of establishments engaged in the manufacture of refractory material is about forty-five.

Of these forty-five works, about forty-one are engaged in making fire-brick, two in retorts and two in glass pots. Careful records of the development of these industries cannot be found, but from the census of 1880 the following figures were secured. The number of fire-brick made in Ohio in 1880, was 19,878,000, which gives Ohio second place in the manufacture of that article, the great iron and steel State, Pennsylvania, alone exceeding this number.

Those two branches which employ the most skill and capital of all clay working industries in Ohio, have been now described somewhat in detail. The branches remaining, with the exception of ornamental clay working, are those in which the commoner properties of clay are involved, and a lower order of skill, but their wide application make their production a large and important industry. They number two—the manufacture of building material and of pipe.

Building Material.

The manufacture of building material is the commonest application to which clay working is put, and it holds precedence of all other branches of clay working in point of labor employed and value produced. The commonest of all manufactured building material, brick, has of course been carried on since the earliest settlement of the State, but the other branches of the work are of more recent introduction.

Special activity is being now manifested in the introduction of new and ornamental forms. They may be classified as:

- Brick —
  - Plain.
  - Pressed.
  - Glazed.
- Tile —
  - Solid —
    - Roofing tile.
    - Flooring tile.
  - Hollow —
    - Building tile.
    - Fire proofing.
    - Flue linings.

All these forms are being produced in the State. The manufacture of common brick will not be considered here, inasmuch as the processes are primitive in their simplicity and are to be found everywhere.

Pressed Brick.

This is one of the newer departments of building material manufactures, but it is making rapid progress. The largest center of manufacture is at Zanesville, Muskingum county, where the natural facilities have been utilized by two large firms, Messrs. Harris Bros., and T. B. Townsend & Co. The former is the largest, and is probably as large as any any one brick establishment in Ohio. Under this firm, three yards in close proximity are maintained, with a working force of about one hundred men, and a daily capacity of 30,000 brick, common and pressed, equivalent to about 9,000,000 a year. The process employed is an admirable one, and could be more widely used with advantage. The clay, which is probably not far from the level of the Lower Freeport horizon, though there are no coal streaks near by to identify it, is yellow and irony; very like the best clays of the drift, though it is a true bedded formation. In its situation it lies within 10 feet of the surface on the tops of several ridges near the town, and it may be an ordinary fire-clay vein weathered to the state in which it is found. It is dug and thrown back in loosely-piled heaps, so that it may further soften and weather. Enough is kept dug to allow it to weather a year before using. It i hauled to the works near by, and is then put into a soaking vat. This consists of a semi-circular depression 3 feet deep, and whose diameter is 30 feet. In the center of the diameter stands a pug-mill delivering away from the vat. This pit is filled with clay by dumping in successive cart-loads from the circumference; when full, the vat is flooded from a hose near by until the amount added will make the whole into a stiff mud. It soaks all night in this way in summer; in winter, wate

is heated in a large cauldron at one side, the flues from which circulate beneath the vat. In this way the clay is warmed first by the water, and then kept warm by the fires underneath. The expense of this apparatus for softening clays is light, and it may easily be put up by any mechanic, and it is found efficient in keeping the works going without interruption all winter.

The clay is pugged as usual and delivered to the molder, who shapes it. The bricks are covered with a yellow-molding sand or earth, which, from the large percentage of iron it contains, assists in giving the bricks the cherry-red color which has done so much to recommend them. The drying is done on an ordinary fire-brick floor. The bricks are pressed in a Miller Brick Press, and again dried. They are all rubbed to remove the wire-edges, etc., and are ready to set in the kiln. The kilns employed here are very large; at the works visited the two kilns were of 320,000 and 215,000 brick capacity, respectively. The walls are permanent and massive; there is no roof but a temporary plank one; the fireplaces are large compound ones, each fireplace heating three arches of the kiln. The burning is from 10 to 12 days, and the cooling 3 or 4. The setting of the kiln is done very carefully; the common brick are used to make the arches, and are piled up to an even height of about 4 or 5 courses above the top of the arch. At the ends and sides they are piled up about 1 yard thick. In the space left, the pressed brick are piled to within 1 yard of the kiln top; above, the common brick are again piled, so that the pressed brick are in shape of a rectangular solid, separated by at least a yard of common brick, from the walls on all sides or the air above and the fire below. By this means the utmost uniformity of burning is secured, and of the production at least 9 shades of color are separated. The brick are each one subjected to a critical examination, and are rejected for a defect invisible to one unpracticed in the examination. Many ornamental shapes are made to relieve the monotony of a plain wall; some of them are only artistic, such as tiles, 1 foot square, containing well-drawn designs, etc. The price of the plain pressed article of any shade is $20.00 a thousand, or 2c. a piece, and ornamental shapes are just twice as much. These Zanesville brick are well known in the markets, and they meet but little competition in Ohio, though Cleveland and Liverpool both make pressed brick. The sharpest competition and the best market is in Chicago.

Glazed Brick.

The manufacture of glazed brick, though of recent origin, is already attracting a great deal of interest and attention among architects and builders. The bricks are of various colors, and are employed to make symmetrical and ornamental designs in building fronts. Very striking effects are obtainable through their use. The coloring, of course, must be put upon an ordinary red or light-colored brick, and the proper mixture of re-agents to make a good enamel on a red clay is a question for pottery decorators to settle; and it seems as if to them it had been intrusted, for nearly all those firms visited, which decorate their own wares, had work of this sort on hand.

Some colors are very easily obtained; the yellows are made by using a simple lead glaze on a cheap, buff fire-brick; blacks are made by a manganese and iron glaze; white and blue are the most difficult to make, as the strong red color, native to the clay, has first to be concealed by an opaque layer of white, which then is finished with a white or blue glaze; green is made in the same way. In the most skillful use of these bricks only a few colors are employed, such as red, black, blue, white, yellow, and possibly green, though all colors can be produced as well as those mentioned. There is no steady source of manufacture of these brick in the State at present, unless, as is possible, the Dover Fire Brick Co. has already started; its preparations were nearly complete in the midsummer (1883.)

Roofing-Tile.

In only a few places in Ohio is roofing-tile manufactured to any extent; the largest and most complete works seen was that of Mr. J. C. Ewart, of Akron.

He uses the Akron sewer-pipe shale as a material for tile, and it answers that purpose very well. The grinding and tempering is done in tracers such as used for sewer-pipe; when tempered it is put into a horizontal cylinder, in which a piston is working; whatever is put into the cylinder is forced out, at the end of the stroke, in a series of parallel plates, about 6 inches wide, by $\frac{3}{8}$ inches thick, and extending along until cut up into lengths. Considerable oil is used to keep the clay smooth and to keep the freshly-pressed plates from sticking. These plates are adjusted, one after another, on a series of discs arranged on the circumference of a revolving circular disc. This disc moves through $\frac{1}{6}$ of its

circumference at a stroke, boring in succession each plate of clay, spread out on its table, under a compound piston. This piston is arranged to cut off the edge of the plate in a symmetrical shape, and then to press it into the required shape. The pressed tiles are removed and set in piles to dry. Drying takes about two weeks, in a steam-heated chamber, as the oil used in the pressing of the clay hinders the escape of the water. They are finally piled in loose order in a kiln to a depth of about 6 feet, and subjected to a light burn. The kilns employed are circular down-drafts. The ware is of several classes—1st, shingle-tile, which are more like shingles than anything else, being slabs of burnt clay $12''\text{x}6''\text{x}\frac{3}{8}''$ with holes in proper places for nailing them to the roof; their uses are as nearly like those of a real shingle as well can be; about 5 inches of each tile are exposed to the weather. The so-called diamond-tile are made to hook into each other, so that on roofs of not too great slant they all support each other, but are also supplemented by nails. They are more ornamental than the shingle-tiles, but as they are more dependent on each other for support, they are not so durable or strong. One of the chief objections to a tile roof is its weight; a ten-foot square of plain shingle tile weighs about 1,100 pounds, and the same area of diamond-tile weighs from 650 pounds to 850 pounds. The advantages claimed are durability, beauty, and immunity from danger by fire or lightning. The factory has a capacity of about 9,000 tile daily, and employs 20 men. There is little competition in the line. Cincinnati has also an establishment for this manufacture.

The use of flooring-tile, other than encaustic, is very limited; the production of a square or hexagonal tile for pavements and cellars is carried on in a few places, but the widest use of such tiles is in making the floors of the fire-brick works.

The manufacture of various hollow-tiles is in a much more vigorous state than that of the flat varieties. Building-tile or hollow-tile, actually laid in a wall with mortar just like stone-blocks, is made in one establishment in Summit county, but nowhere else. The use of this article is so limited that the manufacture scarcely deserves description, but the disposition of the plant for handling the ware is uncommon and ingenious and is likely to be of value elsewhere. The clay is ground and tempered in tracing mills and put through an ordinary "auger" machine which is provided with adjustable dies. The commonest shape is a square tile about 6 inches on a side, 12 inches long, and $\frac{3}{4}$ inches thick.

These tile, as fast as cut, are piled in close order on a car standing beside the machine; when the car is piled two deep, all over, it is replaced by an empty one and is run upon another car whose track lies beneath the general level, and whose top just reaches the floor. The two cars are at right angles. The lower carriage runs past a succession of parallel tracks, all at right angles to its line of direction. At any track the lower carriage can be stopped and the upper run off on either side. The wings of the building are filled with this system of tracks, and, when working, the space is filled in succession with cars of green tile. When dry, this is run out and by a continuation of the same system of tracks run down to the kilns and finally *into* them, so that ware made at the machine is put upon the car, from which it does not move until set for burning. These tracks run further into the yards and are used to draw the kiln as well as to set it. Empties are brought around by a switch to the machine. The whole system is most complete and seemingly economical, and though imperfectly sketched here, the plan can be seen and adapted to any case necessary. The factory produces several grades of tile which are used just like stone or large bricks, and are capable of fairly good service in that line, though any unevenness in burning makes a disagreeable variation of color in the ware, and also the soft plastic clays used allow considerable chance for shrinkage and warping that would be avoided if the tile were subjected to more pressure or made of a stiffer clay.

Fire-Proofing.

This is a technical name for a peculiar kind of hollow-tile, designed to encase the iron beams and girders now so much used in the construction of large city buildings and factories. The beams are of a peculiar shape, and the tile have to be accurately fitted to them to serve the purpose well; when finished, a beam is separated from all outside sources of fire by a double wall of fire-clay and an air-space between. The tile is simply and easily made on an "auger" machine with adjustable dies, and offers no peculiar features in ifs manufacture. It is burned just hard enough to cease shrinking and to expel the water from the clay; where it is most largely produced it is made from the sandy clays used for sewer-pipe. The two largest sources of fire-proofing are Messrs. J. Francy & Sons, at Toronto, Jefferson county, and the Wassall Fire Clay Co., of Columbus.

The manufacture of flues, linings and chimneys for building purposes is altogether done in the sewer-pipe works, and it will be easier to describe the manufacture under this head.

The census of 1880 shows in the table of brick and tile that Ohio produced 296,224,000 common brick in the year, which gives it the 4th rank in the States, being surpassed by New York, Pennsylvania and Illinois. The State has 375 to 400 brick-yards; Cincinnati has 38, and Cleveland 22. In the manufacture of pressed brick Ohio stands 7th, with only 10,365,000 brick to her credit. Under the head of tile, which, however, does not include drain-tile, Ohio stands second, Illinois holding the first rank. The value of goods under this heading is $676,405.00.

Including fire-brick, common brick, pressed brick, tiles, drain-tile, and all other products under this head, Ohio holds 3rd place in the Union, with $3,481,291.00 value of products, and employing over 5,500 hands. New York exceeds it only by $627,000.00, but Pennsylvania is considerably in advance.

Pipe-Making.

The last *large* line of clay working to be described is that of pipe-making; it includes two very distinct branches—1, drain-pipe or tile; 2, sewer-pipe. The former is made on a very large scale in a large part of the State; for wherever the country is flat enough to need draining, on that part is found the generous stock of drift-clays, from which to make the necessary tile. The works making drain-tile seem to be almost if not quite as frequent as brick-yards, and the business is constantly increasing as the farmers become more alive to the advantages attendant on its use. As for sewer-pipe, Ohio produces, according to the census of 1880, four times more pipe than any other State, and as much as the nine next largest put together. The shipping-books of the manufacturers show a market for their pipe in every State, and almost every large city in the Union.

Drain Pipe.

The steady and rapid growth of the production of drain-tile is one of the favorable signs of agricultural progress in the State. As the necessary qualifications are found in any good drift-clay, material is always at hand. The working processes are equally simple and need but a

brief outline to make them familiar to all. The largest and best regulated establishment visited is that of A. O. Jones & Co., Columbus, and from that place this sketch was taken. The clay is dug in a 6-foot stratum, just in rear of the factory, and is carted into the works and dumped into a bin beside the grinding machine. It is here wet down with a hose to the right point, and is then shoveled into the grinder. This consists of two parallel, horizontal rolls revolving towards each other at a distance of $\frac{1}{4}$ inch apart.

On the surface of these rolls are small, gradual depressions and elevations which are arranged on both sides of the center as spirals toward either end. Any particle of hard matter over $\frac{1}{2}$ inch diameter will not catch in the smooth, slippery roll, but by the special motion of the alternating ridges and depressions will be carried off on either side and dropped into an appropriate receptacle, while all clay and soft matter is crushed and deposited on the belt which runs underneath the machine. On this belt it travels to the "auger" machine, into which it is delivered.

The grinder is run at high speed and has no trouble in cleaning enough clay for one large machine to use. The "auger" machine so often alluded to, consists of a cylindrical shell of iron-plate, inside of which works a screw or auger. A hopper at one end catches and collects the clay as it comes from the grinder, and it is dropped upon the revolving screw—it is caught up and carried forward and is soon forced out at the other end through the orifice in the die. The machine has a set of dies from 2 inches to 12 inches, and can make any size at will. Besides the circular tile, by alterations in the die, fire-proofing, square tile, perforated brick, etc., can be made. There are a great many styles of auger machines in use. That made in Tecumseh, Michigan, by Brewer & Co., is a good one, also machines made at Bucyrus, and at Cuyahoga Falls are of good reputation. The shaped clay issuing from the machine is cut in lengths and put on the shelves of an elevating belt. It is received on the upper floors and set on end on the drying floors, of which there are four, all made of slat-work to allow circulation of heat. The roof imprisons the hot air from the engine and boilers, so that the temperature constantly ranges from 90° to 120°. The drying takes from one to three days, by which time the tile is quite hard. The census of 1880 gives Ohio a pre-eminence in this manufacture. The value of drain tile made in 1880 was $834,918.00, about $4\frac{1}{2}$ times as

much as the next highest State in the Union, and as much as the sum of the nine States next in rank.

Sewer-pipe.

The importance of sewer-pipe manufacture, and the foremost position which Ohio takes in it, have been already mentioned. The subject is one of much interest, both as to the manufacture of the material and its proper use when made. The geographical distribution of the sewer-pipe works in the State is as follows: 1st, the Jefferson county district, including eight large works; 2nd, the Akron district, including six large works; 3rd, the Columbus district, including two large works; and 4th, several isolated works, of which the Haydenville factory is the largest. The commercial directories advertise a great many works as sewer-pipe establishments whose real line is the manufacture of drain-tile and such goods. There are two quite well-marked ways of making sewer-pipe, which leads to their classification usually as the river process (that used in the Ohio Valley in Jefferson county), and the Akron process (used at Akron and Columbus). Among the River Works, the Calumet company and Walker's Works are the largest. The process is the same in all cases, and even extends into the manufacture of fire-brick as far as the grinding and tempering goes. The machinery and details have already been described under the manufacture of fire-brick, as well as the character of the clays of the district.

When the clay has been ground, sifted and tempered, it is usually elevated by a belt to the upper story of the works, and deposited in a pin beside the top of the press. These presess are the expensive part of a sewer-pipe plant; there are six kinds in use in the State, though three kinds are found in single instances only. The largest press in use in Ohio is at the Walker Works, Columbiana county. It was made by a Pittsburgh firm, and is the only one furnished by this establishment. The Calumet Works have also two English presses, brought over in the early days of the industry, but they have been almost made over. At the works of the Haydenville company, two presses are in use, made by Spencer, of Steubenville. The other presses in use are made by Barber, of Akron, Stevenson, of Wellsville, and Taylor, Vaughn & Taylor, of Cuyahoga Falls. In those cases noted, the Barber press was in a little the widest use; the other two firms are about equally represented. All the machines act on the same principle, but the mechanical details dffer.

The press consists of a large steam cylinder, upon a high iron frame; the piston runs into a second cylinder of less diameter situated beneath it; this is called the mud-drum or mud-cylinder, and into it the clay to be pressed is introduced, and from its lower end it is forced out as pipe by the pressure from the upper or steam cylinder. The piston at the upper limit of the stroke leaves a passage into the inside of the mud-drum near the top, which is closed as the piston moves down further. Into this opening is shoveled the tempered clay. It is tempered so dry that it may be shoveled with perfect ease, and it has no tendency to stick together by contact alone, though it does so readily by pressure. The cylinder being filled with clay, the piston is given steam and moves down slowly, consolidating the clay and expressing the inclosed air through small holes in the piston head and the cylinder bottom. When, through these holes, the clay begins to issue, the pressman knows that the clay has filled the shape of the cavity perfectly; and as the bottom is a movable one, it is loosened and dropped upon a balanced platform close beneath it. This platform under the weight of the cylinder head, which is so shaped as to form the pipe, is just counter-balanced, and by any pressure can be moved up or down, carrying the socket shaper on its top. The bottom being pushed out of the way, continued pressure from above causes the pipe to issue. When enough has come out, it is cut off by a rotary knife from the inside, and the separated length of pipe is carried away either on a cart or in the hands. It is next sponged and pared, to smooth it. The pipe is shaped by being forced out between the wall of the mud-drum and a conical core which is suspended from higher up in the drum. This cone parts the clay evenly on all sides, and causes it to leave the press in an even, regular shape and thickness. The dimensions of the presses used are various; the Pittsburgh press at Walker's has a steam cylinder 44 inches in diameter, and 23 inches of mud-drum. The ordinary diameter is from 35 to 36 inches, and about 18-inch mud-drum. Those presses which are used for small pipe only are 24-inch cylinders and 12-inch mud-drum. The gang necessary to run a press are: 1st, one man to fill the mud-cylinder; 2nd, one engineer; 3rd, one man to cut the pipe and help handle the pipe; 4th, one man to manipulate the socket shaper; 5th, from one to three men to carry off the pipe. At one of the Elliottsville works, a press is in use having two mud-drums parallel, which are filled and pressed alternately, so that the press may work constantly instead of filling, pressing

and waiting to refill. The drums are shifted backward and forward by a horizontal cylinder to one side. The capacity of a press varies with the kind of clay used, the size of pipe made, and many other conditions, but in normal working, will not vary far from these figures: 36-inch press, making 6-inch pipe, 3,000 feet a day; 12-inch pipe 1,000 feet daily; 15-inch pipe, 800 feet; 18-inch pipe, 650 feet; 20-inch and 24-inch pipe, about 500 feet daily.

The heat used in sewer-pipe burning is only that necessary to get a good salt glaze; about one barrel of salt to a kiln is required. Coal is the fuel invariably used. The finished pipe are, after some coating, stacked up in piles ready for sale. The fittings which go with the pipe, such as curves, elbows, traps, Y's and T's, and all the other special shapes are made by hand in plaster molds. An outline of the process used at the river works has now been given, but it remains to notice the general quality and character of the ware, and the defects and their causes. The river pipe are made from a homogeneous clay, *i e.*, the clay, by the nature of the preparatory steps, is reduced to a fine, even state of division, and by the character of the tempering plant is made into a perfectly uniform paste. And as it enters the pressing chamber in a comparatively fine state, the force which compresses it does not make the lines of demarkation between the particles which composed the mass apparent as it would if the clay were not as soft as it is, and as finely divided. So when a piece of river pipe is broken its fracture shows an even, fine-grained structure, not so fine as stone-ware, but very similar and varying from a buff to a grayish-blue. This latter is the best tint to get, as it insures the combination of whatever impurity the clay contains with the free sand, and development of the best qualities of the clay. The use of salt makes the color a necessity, as a rule, for the combination of iron always begins before the glazing by salt vapor does. The strength that these pipe have is far in advance of any other Ohio pipe, as the structure, seen on the fracture, would show. The degree of heat which the clay will stand without injurious effects is far above the glazing heat of the pipe, and the only precaution in the burning to be observed is to secure enough heat with no close limit on the side of excess. The iron found in these Kittanning clays is present in small grains, which, under the action of the salt glaze, make unsightly black blisters and holes in the surface, though in no degree injuring the utility of the ware; this feature has hitherto much injured its popularity.

It is beginning to receive more credit than ever before, because its superior strength and durability are now being recognized. The color of the river pipe is light-red; in spots, where the heat did not get access to it, it is light-buff, and in over-burnt portions, a dark red color, which has not a pleasing effect. The even, beautiful red color of the Akron and Columbus pipe have been the secrets which have given them the popularity above other kinds, but experience teaches that the color is not essential to the best results. The river pipe, on account of their light, red color, and mottled, spotted appearance, have not had popularity in the West, particularly in Chicago, the greatest of all markets, but they are constantly gaining ground there.

There is in use among railroads and such companies a kind of pipe which is especially fitted for their purposes. It is called among manufacturers the Cincinnati Standard, and the point of difference between it and the ordinary pipe in the market is in the thickness of the shell, which is $\frac{1}{2}$ of its diameter, making a 24-inch pipe 2 inches thick instead of $1\frac{1}{4}$ inches, as usual. This increased thickness is attained merely by diminishing the diameter of the conical core inside the mud-drum, and allowing a wider orifice through which the clay may pass. The river works make this pipe just as easily as they do the thinner kinds, and they claim an advantage here over their competitors who make no thick pipe. The names of the works engaged in clay working in the river-district from Steubenville to Liverpool are:

1. Island Siding Fire Clay Co., Island Siding—brick.
2. Jefferson Sewer Pipe Co., Toronto—sewer-pipe, brick and terra cotta.
3. Forest City Works, J. Francy & Sons, Toronto—pipe, brick and terra cotta.
4. Great Western Works, Francy and Dunspaugh, Toronto—pipe, brick and terra cotta.
5. Calumet Works, Calumet Sewer Pipe Co., Calumet—pipe, brick and terra cotta.
6. Excelsior Works, P. Connor & Co., Calumet—pipe, brick and terra cotta.
7. Freeman's Works, J. Freeman & Co., Elliottsville—pipe, brick and terra cotta.
8. Enterprise Works, Porter, Minor & Co., McCoy's—brick and linings.
9. Adamantine Works, Wilkinson, Steward & Co., McCoy's--terra cotta and brick.
10. J. Lythe & Sons, Wellsville—sewer-pipe and drain-tile.
11. N. U. Walker & Co., Walker's Station—sewer-pipe, terra cotta and brick.

Of these various works, 8 are engaged in the manufacture of sewer-pipe and have in the aggregate 85 kilns in use. At the Calumet works alone, 17 are kept in constant use. This is claimed to be the largest sewer-pipe factory in the United States; its plant consists of 5 grinding

mills, 4 presses, 97,000 square feet of drying floors. Its capacity is about 11,000 tons of pipe yearly, and about 600,000 No. 2 fire-brick as well.

The differences in the manufacture of pipe in the Akron and Columbus district from the river process begin in the material employed. The grinding machinery of the Akron district consist of the machines called tracers, and which have so often been alluded to in other connections. The tracer is an excellent machine for grinding a true clay of a sandy or plastic nature, and though its work in shale is successful, yet it seems as if the heavy wet mill of a fire-brick works could not fail to be better. It would at any rate grind much more in the same time than the tracer, if it did not grind it any better. The fracture of an Akron pipe shows frequently small pieces of shale which have escaped the wheels, and in burning, these pieces usually shrink away from the bond clay so as to make a loose spot in the pipe, and they are consequently weakening in their effect. As the test of a wet mill has been nowhere made, it would surely be a valuable contribution to that district if some operator gave it a fair trial.

The grinding takes from 45 to 50 minutes, and about 1,200 pounds constitute a charge; the water used is added by the bucketful, and the clay is tempered very stiff. In many works they use only $\frac{2}{3}$ as many machines as necessary, and run part of their plant all night to get the necessary clay for the next day's campaign. The Akron works all use the Barber machines, though some of them are of the new style; traces are made by the Cuyahoga Falls Co. The ground clay is shoveled into a squeezer either of the screw or piston type, and it is concentrated into a long compact cylinder about 6 inches or 8 inches in diameter. This is cut up in lengths of about 15 pounds weight and is fed to the machine in that shape. From this results the worst trouble of the Akron pipe; the stiffness of the clay and the large, well-compressed wads in which it is fed, act together in keeping the clay from uniting to a homogeneous mass. Even under the powerful pressure of the machine the lines of demarkation between the different pieces going to make up a pipe, are plainly to be seen on the fracture of a burned pipe. They are arranged in circles concentric to the outside of the pipe, and often a crack $\frac{1}{16}$ of an inch separates the layers of the clay. This is all developed on burning, but is not visible before to any such degree. The working of the clay is admirable. It issues from the press as smooth as if molded

with oil, and the sockets are beautifully true and correct. The drying, setting and burning need no special attention. The kilns used are just like the stone-ware kilns; they are oblong, end-fired down-drafts, about 30 to 35 feet long, and 15 to 20 feet wide, with an average capacity of about 40 tons. The burning takes six days.

The character of Akron ware has already been hinted at in the description of the river pipe. It is a smooth, handsome ware, well-shaped, of a beautiful dark, red-brown color, and remarkably uniform. On its fracture it shows the red color of a brick or even a darker, which shows the presence of iron in that peculiar state so hard to define, which is necessary to the development of the high color; the per cent. of iron must be high, yet but little of that offensive blotching seen on the river ware can be noticed. The weakening of the whole structure by the concentric cracks due to the pressing is the worst fault of the pipe.

As to the inability of the Akron works to make the Cincinnati Standard pipe, this is to be said. The increase of thickness of their pipe, with the same amount of drying which they now give it, is liable to cause large flakes to spall off from the sides of the pipe when heated in the kiln. With a longer and hotter drying they could make these thick pipe, but as their capacity is used to the fullest rate now, they are under no necessity to begin its manufacture. One point where they hold a decided advantage over the River district, is the use of the patent device for making curves, elbows, S's and traps. They can control the position of the core inside the mud-drums by a lever, and by moving it so as to make one aperture smaller than the other, the clay issues the fastest on the thinnest side and the pipe takes a curve shape. Also by using a softer clay on one side than the other, the softest part issues faster and the pipe curves. The use of the movable core is so nicely manufactured that such curves as the letter S, and the stench traps, can be made without help from the hands. This is a patented principle, and the Akron works have a monopoly on it, and refuse to share with other parties.

The catalogues and circulars of the Akron manufacturers claim that they sell a *vitrified* pipe. But the word *vitrified* has a definite signification. It would require, if properly applied, that the clay should have been fused to a glass, or that it should have undergone incipient fusion, or that its free silica and fluxing impurities should have been made to combine. But none of these conditions are met. The fracture of the Akron pipe is not in the least vitreous. On the contrary, parti-

cles of the mass, such as pieces of shale, can frequently be seen separate and distinct from the body clay. The color also of combined oxide of iron and silica is dark, running from blue to black, while the color of uncombined oxide of iron is red; the color of the Akron pipe is red, showing that the impurities are not in a state of combination. But though the pipe is not vitrified, it is probably better than if it were, for the excess of the iron in the clay would tend to make it brittle if it were in real combination. In other words, vitrification would possibly be not only an undesirable but a dangerous quality in a sewer-pipe. The pipe manufactured by Messrs. Sperry and Rattle at Tallmage, shows more nearly a truly vitrified fracture than any seen in the district. Judicious experimentation with powdered feldspar, salt, potash solution, or any fluxing agent, would very soon establish the practicability, and test the advantage of making the pipe vitrify throughout. The Akron pipe probably have as wide a distribution as any similar manufactured product in Ohio; they go in all directions and in all quantities. The four works in Akron have a yearly capacity of 5,000 car loads. The largest works, the Akron Sewer-Pipe Company, have 3 presses, 12 kilns, and employ one hundred men. They make pipe by both steam and water-power. This factory also claims the distinction of being the largest in the country; it requires a close comparison to decide between this and the Calumet works. The position of Ohio in the sewer-pipe business has been mentioned. There are no records available which show the exact condition, as the census returns make no mention of it, but Ohio's annual product is probably about $3,000,000 in list price, which is subjected to a variable discount. The number of works of considerable size and prominence is seventeen. The nearest competitor among the other States is New York, which has probably about half the development that we have. The States rank in production: Ohio, New York, Missouri, New Jersey, Illinois, Pennsylvania and Indiana.

Ornamental Clay Working.

The only artistic applications to which clay is put in Ohio are the manufacture of encaustic tiling, ornamental pottery and terra cotta.

Encaustic Tiling.

This beautiful ware is manufactured in only three places in the United States at present, among which the works at Zanesville were

the first to be established, and their products have attained as high a grade of perfection as any. The name of the Zanesville firm is the American Encaustic Tiling Company, Geo. Stanberry, superintendent. The stock is chiefly owned in New York, and nearly all the products of the works are sold there, in the face of foreign competition. Our best tiles are as good as the best of the English and French, but the average of foreign tiles exceeds the average of the home manufacture. The clays used are of many kinds; those varieties used in largest proportion which constitute the "body" clays, and are found in the immediate vicinity of the works, but the clays which are used for the more delicate processes, come from widely scattered and distant localities. In making colored clays, the effort is to obtain a clay as nearly right naturally as possible, and then to correct it with the necessary reagents, rather than to undertake to establish a new color in a clay. The process in outline is as follows: The clays are washed or beaten up to a slip in a "blunger," and while in this state the necessary metallic oxides are added to color them. The slip is strained and evaporated to a paste in iron-lined tanks. This paste is stacked up in open cribs in a tight steam-heated room, and the clay is then retained until *perfectly* dry. It is then reduced to powder and uniformly moistened, but so slightly that it is not perceptible to the hand, and in this state it is molded. Each kind of powder, though probably indistinguishable in appearance from others, has the elements in it which will develop its own color. The presses are ingeniously devised machinery, the invention of Mr. Stanberry; the plant of the works in this regard is as efficient as any in operation anywhere. The simplest tiles are made from clay of one color, and the process consists of stamping so much clay powder into a confined space, and consolidating it by enormous pressure. Next come those tiles made of two colored clays; the first stamping makes the body but leaves indentations in its surface, into which the second clay is put, and this is pressed into place; the tile is then scraped to get a cleanly-drawn line of both colors and again stamped with a flat die. The most complex tiles show six colors on their face, and have a band of a seventh kind of clay running through the centre to keep the complex mixture from warping. These tiles are subjected to frequent tests, to see if the force of compression and degree of moistening is correct. They are dried in steam-heated closets for as much as six weeks after pressing, in order to insure their perfect dryness before burning. The burning is done in

saggers, like china-ware, and with fully as much care. The kilns are in all respects like the china-ware kilns of East Liverpool. The tiles are sold in the biscuit state or are glazed, plain colored or majolica. Some tiles are also enameled and carved by hand designs, etc.; this class of work is very expensive, as all really artistic work is. The working force of men employed is large, but the management are so far enabled to keep all the important points of the work under their own immediate charge, so that an attempt to learn the secret of the trade from the workmen would be fruitless. A good illustration of the way in which a successful venture is copied may be seen here in Zanesville, where a rival stock-company has been formed, and is starting out with nothing but money to rely upon in a difficult technical art, like that of making encaustic tiling.

Ornamental Pottery.

Another establishment, the only one of its kind, and reflecting equal credit on the State, is the celebrated Geo. Ward Rookwood pottery, of Cincinnati. It is owned by Mrs. Nichols, and is under the management of Mr. Cranch. It is devoted entirely to the production of ornamental pottery. Both molded and turned wares are manufactured in great variety, from the antique to the most modern styles. In decoration there is also equal range, over-glaze, under-glaze and smear-glaze decoration being all carried on, and some vase gilding as well. The artists employed are each of them specialists of a high rank of excellence. Among them, Miss McLaughlin's work in particular is sought after, and she is credited with being the inventor of the style of decoration called the Cincinnati faience. The elegant wares made at this place take rank side by side with the best of foreign production.

Terra Cotta.

Terra Cotta is divided into two kinds—useful and ornamental. The useful kinds are chimney-tops and flues. The ornamental forms are lawn vases, fountains, statuary, etc.

There is room for the exercise of taste and skill in making some of these higher grades of wares.

The flues and chimney-tops are made on ordinary sewer-pipe presses, either with or without a socket. Square flues are made by putting on

special dies made for the purpose. The more artistic chimney-tops and all the other kinds of ware are made in molds. In the manufacture of terra cotta, the development of the possibilities of molds is better illustrated than in any other line of clay working. In the preparation of the clay, which is usually a gritty plastic clay, there is no special precaution taken, unless it is a little longer grinding than for sewer-pipe. The molds are filled by hand. In making statuary and busts the mold used consists of an outer shell with proper handles cut in it by which it can be lifted off as a cover from the inside part. The mold is filled when in an inverted position; the cavity is seen in its proper shape, and the walls of it are made of a great number of small blocks which fit together perfectly. The cavity is filled by hand and the mold is then inverted, the outer shell withdrawn, and the blocks removed one by one and put back into place, leaving the figure desired in clay. Some pieces of statuary of small size have more than 100 blocks inside the outer shell. Real terra cotta burning should be done in a closed chamber. In only one establishment, viz., the Wassall, Fire-clay Works, of Columbus, is it done; their kiln consists of an inner kiln, in which the ware is piled and secured, and which is then shut and luted with clay and an outer kiln, which carries the heat on all sides of the interior cavity. The fuel used to make the interior kiln red-hot is in quite large amount, but the pure color and absence of spotting of the ware repays the trouble. When terra cotta is burnt in open kilns like pipe it is burnt harder, but is not nearly so light-colored or handsome. The clays of the river district make an admirable terra cotta, but are all burnt in open sewer-pipe kilns; and they have contributed one point of some value to the theory of burning of clays. On the light-colored terra cotta it is found at all times that the surfaces exposed to the action of the down-draft, *i e.*, all the upper surfaces of the ware are covered with a fine red powder which seems deposited on these places, just as snow which descends slowly will cover the upper side of every object exposed to the weather. This red powder can be partially removed, but at the heat at which it is burned part of it sticks to the ware, and will not come off. It consists of particles of ash and other debris from the fires, and deposited probably during the whole process of burning; but as the wet ware accumulates soot an inch thick when it is first heated, it may be that the soot is what catches the flying particles, which are left as the soot burns away. At any rate the point is proved that the draft of a kiln carries in a very

perceptible amount of irony and fluxing materials which tend to flux the outside of the ware and give it the dark appearance that runs along the arches and exposed parts of the brick kilns, etc. This is usually attributed to "sulphur in the fuel", etc., but its explanation is found in the above facts. The only way to obviate this difficulty is to burn terra cotta in closed spaces, or to put up a net-work of surfaces which shall catch this dust before it touches the ware. If the draft from every fire-place were made to pass through a cubic yard or so of bricks closely piled, they being both the hottest parts of the kiln, and the most exposed would probably act as strainers to their respective fires, and would eliminate part of the trouble, if not all.

Nearly all the river works make terra cotta, but at N. U. Walker's, the best ware of this district, and the most of it, is made. This is probably the largest terra cotta factory in the United States. It has a tempering plant for terra cotta alone, a sewer-pipe press for linings and chimneys, and has 6 kilns, three of which are very large ones. His daily product would amount to 24 tons of ware, about 20 in flues, etc., and 4 in statuary and finer grades of work. The Wassall works, at Columbus, make but a small amount, but in the finish and execution of what they turn out they take the first rank.

CHAPTER X.

THE GAS COALS OF OHIO.

BY EMERSON McMILLIN, *Superintendent of Columbus Gas-Works.*

To determine the commercial value of any particular coal for gas-making, several points must be considered. First, convenience to market; second, quantity and illuminating power of gas to be obtained from the coal; third, character and weight of coke; fourth, freedom from impurities.

The first point—convenience to market—is one of great importance. Mines located along navigable streams and water-ways for transportation, have greatly the advantage of coal that must be transported by rail, Youghiogheny coal being carried down the Ohio river, a distance of 500 miles, to the largest market of the State, at a less cost than coal can be transported by rail from the great coal fields of Hocking and Perry counties, distant only 120 to 200 miles from the same market.

So far but little effort seems to have been made to introduce the coals from mines located along the Ohio river, in this State, into gas-works.

The great Pittsburgh seam is accessible to the river at several points, and notably so at Pomeroy. The coal from the numerous mines at Pomeroy has been in the market for many years as a favorite domestic and steam coal, and recently it has been tried at some gas-works in this State and in some Eastern cities with fair results. The coal tested, however, was rather better than the coal known in the market as Pomeroy or Ohio river coal, it being from a mine recently opened, but still in the Pittsburgh seam. Could the rich cannel coal of numbers 3, 3*a* and 3*b* seams, mined in Vinton, Jackson, Licking and other counties of the State, be put into gas-works at same cost as Youghiogheny coal, the former would be very largely used, and possibly to the exclusion of the latter, where gas of high illuminating power is sought for.

This brings us to the second point of consideration—quantity and illuminating power of gas to be obtained from a given quantity of coal.

Coal yielding 4 feet to the pound is not worth four-fifths the value

of coal that yields 5 feet to the pound. The use of the richer coal reduces the cost of necessary plant, labor in retort house, wear and tear of retorts, and the consumption of coke for fuel. The illuminating power being the same, and the value of the richer coal being placed at $2.50 per net ton at gas-works, then the value of the leaner coal will not exceed $1.95, and probably not $1.90, especially to small works, not using or disposing of their ammoniacal liquor. But, as a rule, the richer coal gives gas of a higher illuminating power than does the leaner article. Coal giving a high candle power gas often possesses great value, even when giving an inferior coke, and not extraordinary yield in quantity, in this, that it may enable the gas-works to use a poor coal, or a coal that makes a low candle-power gas, but which from its nearness or convenience to the works, can be obtained, relatively, much cheaper than good gas coal.

General figures and calculations cannot be given that will be of much value or interest to works in any particular locality, but with the number of gas-works located in the coal producing territory of the State, it seems that by a proper admixture of the local coals that can be obtained cheaply with the cannel of numbers 3, 3*a* and 3*b* (the Mercer and Tionesta coals), a much greater quantity of Ohio coals might be used with profit to the gas companies.

In many localities local coals, say of numbers 5 or 6 (the Kittanning seams), may be obtained at $1.50 per ton, and cannel at $3.00 per ton. Number 5 will produce 9,000 feet to the net ton of 13 candle gas. No. 3 cannel, 9,000 feet, of 24 candle gas, the mixture giving a coal at $2.25 per ton that yields 9,000 feet of 18.5 candle gas, with good coke from half the coal, and inferior coke from the other half or from the cannel coal.

Weight and character of coke ranks third in determining the value of gas coals. In both quantity of coke produced from a ton of coal, and in the quality of such coke, Ohio coals are generally inferior to Youghiogheny coal. The Pittsburgh seam in Ohio gives a coke inferior only perhaps in quantity of sulphur it contains, and possibly a slight excess of ash.

The number 5 seam, of southern Ohio, gives a coke very similar in appearance to Youghiogheny, but carries so much sulphur as to be useless for many purposes for which good coke is used. Number 6 seam gives a lighter and more pulverulent coke, containing more sulphur than the Youghiogheny gas coke. Its structure is such as to cause it to be consumed with greater rapidity, producing intense heat and fluxing

the ash to a greater degree than is the case with Youghiogheny gas coke.

The fourth and last general point to be considered in determining the value of any particular coal for gas making, is its impurities. The term impurity is here used in the sense that is usually applied in the gas-works of the United States, and particularly in the smaller works, referring to the sulphur compounds, sulphuretted hydrogen and bisulphide of carbon.

An analysis for total quantity will not always determine the question whether a coal contains a too large per cent. of sulphur to be profitably used in gas making. Two coals containing equal per centages of sulphur may produce gas—the one easily purified, and the other foul and hard to purify. But the question of purification is one of much less importance now in determining the value of coals than was the case a few years ago.

The general adaptation of oxide of iron, in its various forms, has so reduced the cost, that the expense of removing the sulphuretted hydrogen has become almost nominal.

But lime is still used for the removal of bisulphide of carbon and carbonic acid.

Ammonia, in its various forms, has not here been treated or considered as an impurity, as the cost of removal in small works is insignificant, while in the large works the ammonical liquor is often a source of revenue.

Both carbonic acid and carbonic oxide are impurities and are produced to a greater extent by the use of some coals than by others. Yet we have not considered either of these impurities in making suggestions for the determination of the value of gas coals, as the manner of manipulation often has as much to do with, and is as much at fault in the production of these impurities, as is the character of the coal.

Coal having no definite composition, and coals of almost identical composition as ascertained by ultimate analysis giving totally different results when distilled in a gas retort, renders it impossible to lay down any positive rule for judging a good gas coal by its analysis. But it is safe perhaps to say that the gasmaker should choose the coal that contains the largest per cent. of hydrogen and the smallest per cent. of oxygen. While it is well known that the combustion of hydrogen at the ordinary pressure of gas consumption, results simply in producing a blue flame without light, and it is equally certain that the light of

the gas flame is produced by the incandescence of the carbon of the gas; still, as before stated, the best gas coals are those which contain the largest per cent. of hydrogen, and consequently smallest per cent. of carbon, and the less oxygen the better.

The larger the per cent. of hydrogen that coal contains, the greater the quantity of carbon that can be volatilized, and the combustion of the hydrogen at the tip of the gas burner is necessary to produce the proper degree of temperature in the carbon to give us the incandescent light, and to eventually promote the ignition of carbon, and its conversion to carbonic acid, and thereby preventing the escape of free carbon and the creation of smoke and deposition of soot.

The analysis of the best gas coals often shows the per cent. of ash so great as to be almost beyond belief. The coke from Boghead cannel, a coal that yields 13,000 to 15,000 feet of thirty-five to forty candle power gas, has analyzed 70 per cent. of the weight of the coke in ash. Other good gas coals of the cannel character, range down to 20 per cent. of the weight of its coke in ash. Coals used in gas-works of this and other countries vary in quality from one grade yielding 6,000 feet to the net ton of thirteen candle gas, up to 12,500 feet of 131 candle gas; the latter coal, if coal we are permitted to call it, being known as the Hartley mineral of New South Wales—the one yielding thirty-nine candle feet to the pound, the other yielding eight hundred and twenty-nine candle feet to the pound.

The Albertite of Nova Scotia will yield 13,300 feet to the net ton of nearly fifty candle gas, or three hundred and thirty candle feet to the pound. Grahamite, of West Virginia, 13,500 feet of twenty-eight candle gas, or one hundred and eighty-nine candle feet.

But few persons can realize the magnitude of the gas industry of this country. There are now in the United States more than seven hundred incorporated gas companies, doing business with a capital of over two hundred millions, and employing more than twenty-five thousand men. Just what amount of capital is employed in this State in the manufacture of and distribution of illuminating gas, could not be ascertained by the writer, but as more than ten per cent. of the total gas-works of the country are located in Ohio, it is probably not too high an estimate to place the capital at 7½ per cent. of the total, or about fifteen million dollars, and this business has grown up almost entirely during the last generation. The first gas-works of the State were built

in Cincinnati, in the year 1842; the town being first lighted January 14, 1843; the second at Cleveland during the year 1849, and the third at Zanesville, same year. There are seventy-five gas-works now in operation in the State. Ten years ago, prices for gas ranged from $2.50 to $5.00 per thousand feet. Prices now range from $1.25 to $3.00. With the rapid growth of towns and cities and consequent increased demand for gas, the companies have been enabled to correspondingly reduce the price. While the growth of the business has been rapid, we are led to believe that the business will make much more rapid strides during the next than during the last decade; and this notwithstanding the introduction of lighting by electricity. In fact, so far the new light has rather helped than hurt the gas interest. It has apparently spurred the companies to seek new fields, to introduce improved apparatus, to lower the price of gas and thereby stimulated its use for motive power and for cooking and heating stoves, and in many ways the business has been increased to a degree that far more than compensates for the loss of the few consumers that have substituted the electric light for coal gas.

One of the best authorities of the State gives it as his opinion that a capital of $8.00 per one thousand feet, or a capital equal to $8.00 for every one thousand feet of annual production, is about what is required in this country to construct and successfully operate a plant for the manufacture and distribution of gas. This is too large for large cities and too low for small towns, but the average is not far from right, and, figuring upon this basis, the capital employed in this State should be about what is given on a previous page, viz., fifteen million dollars.

In reply to inquiries made of all the gas-works in the State, only about 18,000 tons of Ohio coal is reported as being used in the gas-works of the State during the year 1882.

While many works failed to respond to the inquiries, it is believed about all did so that are using native coal. It would be quite within bounds to say that not to exceed 25,000 tons per annum of Ohio coals are used in the great industry of making illuminating gas. This is less than 10 per cent. of the total quantity used.

This may be accounted for—first, from the fact that the Ohio coals are generally dryer burning, and containing less bitumen, making a lighter and more pulverulent coke, and containing less volatile combustible matter; second, from the fact that Cincinnati, a city making about one-third of all the illuminating gas that is consumed in the State, can

be supplied with the fine gas coals of the Youghiogheny region, at less cost per ton (river transportation) than the leaner Ohio coals can be delivered for. Again, Cleveland, the next largest city in population, and second only to Cincinnati in gas consumption, and making about one-fifth of the total production of the State, can be reached with Pennsylvania coal of superior quality with less cost than coal can be delivered from the principal coal fields of Ohio. Columbus, making about onè-tenth of the total production, has for a number of years used coal from the Hocking coal fields, almost exclusively—the inducement being a short haul from the Hocking Valley, while a long haul by rail is required to deliver the Youghiogheny coal to the Capital city.

Coal is used for gas-making from several seams of the Ohio series, yet the Middle Kittanning seam, No. 6, probably furnishes three-fourths of all that is used in gas-works.

The reports from a number of gas companies show that an average of not to exceed 3.75 feet of gas to the pound is obtained from this coal, though some works do much better. The coke seems to be a favorite one for base-burning stoves, and some classes of smithing, but for the cupola and blast furnace purposes it is quite inferior to the oven coke of the Connelsville region, or to the gas coke made from Pittsburgh or Youghiogheny coal. A cannel coal obtained in several localities from the number 3, 3*a* and 3*b* seams has been used to a limited extent, and may yet be developed into one of the principal gas making coals of the State.

The seams are generally thin, and have not been much developed along lines of railroads, or if on railroads, then quite distant from the larger cities. The Lower Kittanning coal, No. 5, has been used at several of the smaller towns for many years. This coal is reported to yield $4\frac{50}{100}$ feet of gas to the pound of coal, and the coke from it is superior to that made from the number 6 seam (except that it contains more sulphur), or from either of the other seams, excepting only number 8, or the Pittsburgh seam.

It is doubtful if any coal in Ohio is entitled to the distinction of being classed as strictly a gas coal. There are probably twenty-five, and not to exceed thirty gas-works in the State that use Ohio coal exclusively, and a few others that use it in part as a mixture with Youghiogheny coal. Generally these works are small.

Sufficient importance does not seem to be attached to the difference

in coals for producing gas. For instance, one coal will produce 4 feet of 14.5 candle gas, another 4.40 feet of 16 candle gas. Now, if the two coals produce about the same weight and character of coke, it is quite a common error to rate the second coal as about 10 per cent. better than the first. As the object to be attained in the decomposition of coal is light, a simple calculation will show the fallacy of such rating:

$$4.40 \times 16 = 70.40 \text{ candle feet.}$$
$$4.00 \times 14.5 = 58.00 \text{ candle feet.}$$

Difference, 12.40 candle feet.

Or, 17.61 per cent.

In most mines of this State driven in on coal No. 6, or the great vein, there are found three members of the seam, the lower member being the softest and apparently the best part of the vein. The second member is much the thickest and usually of good quality. The third or upper member is sometimes missing, and often of poor quality, containing a large per cent. of ash. In the Hocking Valley district this member is often left to form the roof of the mine.

Sometimes this member is found to be a fair cannel coal, very rich in light-producing gas, as is shown by test numbers XIV and XVI; the yield of gas is quite good, and the quality of the gas most excellent, being of higher illuminating power than was obtained from a test of the justly celebrated cannel coal of the Kanawha Valley. Whether there is sufficient quantity of this coal that partakes of the cannel characteristics to make it of economic value, the writer is not prepared to say. The question is one, however, worthy of thorough investigation.

The coke made from this coal or cannel is very inferior, containing a large per cent. of ash.

The presence or absence of this cannel in coal purchased by gas-works will in a measure account for the very different results obtained by the different works of the State that have used Hocking coal.

With a proper admixture of the lower members of the seam with the cannel, very fair results may be obtained.

Assuming that a mixture of the two lower members of the seam will produce four feet to the pound, or 8,000 feet to the net ton of 14 candle gas, and that the cannel will produce four and a half feet or 9,000

feet to the ton of 19 candle gas, then a mixture of three-fourths cannel and one-fourth coal will produce,

$$\begin{array}{lll} 1\times 8= \ 8 & \text{and} & 8\times 14=112 \\ 3\times 9=27 & \text{and} & 27\times 19=513 \\ \hline 4)35 & &)625(17.86 \\ \hline \end{array}$$

8,750 feet of 17.86 candle gas.

Half cannel and half coal will produce,

$$\begin{array}{ll} 8\times 14=112 & \\ 9\times 19=171 & \\ \hline 2)17 &)283(16.65 \\ \hline \end{array}$$

8,500 feet of 16.65 candle gas.

One-fourth cannel and three-fourths coal will produce,

$$\begin{array}{lll} 1\times 9= \ 9 & \text{and} & 9\times 19=171 \\ 3\times 8=24 & \text{and} & 24\times 14=336 \\ \hline 4)33 & &)507(15.36 \\ \hline \end{array}$$

8,250 feet of 15.36 candle gas.

By the analyses made by Prof. Wormley, as published in the first volume of the Ohio Geological Survey, it is clearly shown that but a small per cent. of the sulphur in some of the coals analyzed was in combination with iron. What the combination really is, I believe is unknown.

As before stated, analyses show that in some coal nearly all of the sulphur passes off in the gas, while with others a very large per cent. remains in the coke. It is quite probable that the conditions of the analysis have much to do with bringing about these results, and that two analyses of the same coal may, in one instance, give coke nearly free from sulphur, and the other show most of the sulphur remaining in the coke. In the volume just referred to it is stated by analysis, or rather by carbonization, Pittsburgh coal is shown to yield 3.50 feet of fourteen candle gas per pound of coal, and the Hocking coal is shown to yield 3.30 feet of eighteen candle gas.

The fact is, that good Youghiogheny or Pittsburgh coal, yields in all large well managed works, 4.75 ft. to 5.25 ft. of 15 to 17.5 candle gas to the pound of coal, while by actual tests, as shown in this chapter,

the Hocking coal yields, leaving out the cannel of No. 6, 3.75 to 4.20 feet of 13 to 15 candle gas per pound of coal carbonized.

The difference in results obtained in practice now and by the laboratory tests made twelve years ago, seems too great. However, this difference is partially accounted for by the fact that gas-works are now making a much greater yield of gas than was obtained from the same kinds of coal used ten or twelve years ago, when it was conceded by Prof. Newberry that in practice, gas-works were able to get 4 feet of gas from Pittsburgh coal. It often occurs that the samples selected for analysis by parties interested in having a good report therefrom will be coal from the part of the seam containing the least volatile combustible matter. Again, the temperature of the crucibles of the laboratory is usually below that of a good working retort in gas-works, and the result is, that a larger per cent. of tar and oils are produced with a less quantity, but better quality of gas. But the greater difference in the results obtained doubtless occurs in the length of time the vapors—permanent and condensable—are in contact with the highly heated surface of the retorts. In the laboratory the vapor rapidly escapes and probably retains, on its exit from the crucible, the same chemical composition it possessed when bursting from the lump of coal, largely condensable at atmospheric temperature, and the permanent gases composed of the richer grades of hydro-carbons, while in gas-works practice, the vapor is required to travel slowly a distance of two to ten feet, and to be brought in contact with the hot surface of the retorts and of the highly heated coal and coke. In this manner the condensable vapors of the laboratory are decomposed in the retort and converted into permanent gas, and the heavier hydro-carbons are broken up into hydrogen and solid carbon or soot, the volume of gas being thereby augmented, but the illuminating power of an equal volume of the gas being largely reduced, though the actual candle feet or total light obtained from a ton of coal will be greater with high than low heats.

The tables given below show the result of tests made by one of the larger gas-works of this State. The tests were first made on a small scale, 150 to 200 pounds, and afterwards generally repeated and the results verified on a larger scale, using 75 to 100 tons.

The engineer making these tests, for the sake of convenience in comparison, assumed that the gas weighed 26 feet to the pound, or a specific gravity of about 500, air being 1,000. The "loss" reported is

not easily accounted for, at least not all of it. By one of the tests it is shown that the weight of lime used in purifying the gas increased 2.75 per cent. and this will doubtless apply to all the other tests. Still there is a large per cent. unaccounted for of the material charged. Doubtless much of it may be accounted for by the wasteful method of charging the coal into the retorts with a shovel or common coal scoop. From the time the first shovelful is thrown into the retort until the charging is completed and the lid put on the mouth-piece, there is a rapid generation of moisture and heavy hydro-carbons. Much of the the volatile matter escaping at this time is condensable, in the main and tar scrubbers, and is very heavy as compared with the gas that enters the holder.

But the loss is not peculiar to the works making these tests nor to the American practice, as will be seen by glancing at the tables presented on a another page, where tests of English coals are given. The loss there is reported quite as heavy as the loss shown here. In these tests the tar and ammoniacal liquor is separated by gravity, and it is possible, indeed quite probable, that had the liquid been permitted to settle for some hours before being separated and weighed, more tar would have been precipitated and the per cent. of tar increased and the per cent. of liquor correspondingly decreased.

Test number I.—Hocking Valley coal, from the great vein, or No. 6 seam:

Coal charged into retort, 150 pounds.
Total gas made, 576 feet.
Gas made per pound coal, 3.84 feet.
Candle feet obtained, 52.76.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	22.15	14.77
" coke	86.50	57.67
" tar	5.00	3.33
" liquor	9.00	6.00
" lost	27.35	18.23
Total	150.00	100.00

Test number II.—Hocking Valley coal, from the great vein, or No. 6 seam:

Coal charged into retort, 150 pounds.
Total gas made, 609 feet.
Gas made per pound coal, 4.00 feet.
Candle feet obtained, 56.84.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	23.42	15.61
" coke	94.00	62.67
" tar	4.00	2.67
" liquor	10.50	7.00
" lost	18.08	12.05
Total	150.00	100.00

Test number III.—Pittsburgh coal, from mines along Pan Handle Road:

Coal charged into retort, 150 pounds.

Total gas made, 649 feet.

Gas made per pound coal, 4.33 feet.

Candle feet obtained, 69.28.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	24.96	16.64
" coke	98.00	65.33
" tar	2.50	1.67
" liquor	7.50	5.00
" lost	17.04	11.36
Total	150.00	100.00

Test number IV.—Pomeroy coal, from Pittsburgh seam, Antiquity, Meigs Co., O., Coke equal to Pittsburgh:

Coal charged into retort, 150 pounds.

Total gas made, 669 feet.

Gas made per pound coal, 4.46 feet.

Candle feet obtained, 75.82.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	25.73	17.15
" coke	106.00	70.67
" tar	2.50	1.67
" liquor	9.27	6.18
" lost	6.50	4.33
Total	150.00	100.00

Test number V.—Hocking Valley coal, from the great vein, or No. 6 seam:

Coal charged into retort, 150 pounds.

Total gas made, 598 feet.

Gas made per pound coal, 3.98½ feet.

Candle feet obtained, 51.80.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	23.00	15.33
" coke	89.00	59.33
" tar	3.50	2.33
" liquor	9.50	6.34
" lost	25.00	16.67
Total	150.00	100.00

Test number VI.—Pomeroy coal, from Pittsburgh seam, Antiquity, Ohio:

Coal charged into retort, 150 pounds.

Total gas made, 651 feet.

Gas made per pound coal, 4.34 feet.

Candle feet obtained, 75.95.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	25.04	16.69
" coke	102.00	68.00
" tar	3.00	2.00
" liquor	10.00	6.67
" lost	9 96	6.64
Total	150.00	100.00

Test number VII.—Hocking Valley coal, from the great vein, or No. 6 seam:

Coal charged into retort, 200 pounds.

Total gas made, 799 feet.

Gas made per pound coal, 3.99 feet.

Candle feet obtained, 59.85.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	31.	15.50
" coke	122.	61.
" tar	4.50	2.25
" liquor	18.	9.
" lost	24.50	12.25
Total	200.00	100.00

Test number VIII.—Cannel coal, from Flint Ridge:

Coal charged into retorts, 200 pounds.

Total gas made, 900 feet.

Gas made per pound coal, 4.50 feet.

Candle feet obtained, 108.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	34.62	17.31
" coke	122.00	61.00
" tar	3.50	1.75
" liquor	7.50	3.75
" lost	32.38	16.19
Total	200.00	100.00

Test number IX.—Kanawha cannel, from Cabin Creek, W. Va.:

Charged coal into retorts, 200 pounds.

Total gas made, 1,000 feet.

Gas made per pound coal, 5 feet.

Candle feet obtained, 94.50.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	38.46	19.23
" coke	128.00	64.00
" tar	5.00	2.50
" liquor	3.00	1.50
" lost	25.54	12.77
Total	200.00	100.00

Test number X.—Hocking Valley coal, mostly cannel, from the great vein, or No. 6 seam:

Coal charged into retorts, 200 pounds.

Lime put in boxes, 80 pounds.

Total gas made, 840 feet.

Gas made per pound coal, 4.2 feet.

Candle feet obtained, 73.50.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	32.31	16.16
" coke	116 00	58.00
" tar	8.50	4.25
" liquor	23.00	11.50
Increase in weight of lime	5.50	2.75
Loss	14.69	7.34
Total	200.00	100.00

Test number XI.—Pittsburgh coal, from Rend's mines:

Coal charged into retorts, 200 pounds.

Total gas made, 1,000 feet.

Gas made per pound coal, 5 feet.

Candle feet obtained, 75.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	39.	19.50
" coke	123.	61.50
" tar	13.	6.5
" liquor	19.	9.5
" lost	6.	3.
Total	200.00	100.00

Test number XII.—Youghiogheny gas coal, Shaner mines, retort leaked:

Coal charged into retorts, 200 pounds.

Total gas made, 920 feet.

Gas made per pound coal, 4.60 feet.

Candle feet obtained, 78.25.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	37.	18.50
" coke	138.	69.00
" tar	5.50	2.75
" liquor	12.00	6.00
" lost	7.50	3.75
Total	200.00	100.00

Test number XIII.—Youghiogheny gas coal, from Shaner mines:

Coal charged into retorts, 200 pounds.

Total gas made, 1,042 feet.

Gas made per pound coal, 5.21 feet.

Candle feet obtained, 86.57.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	40.	20.
" coke	135.	67.50
" tar	9.50	4.75
" liquor	14.	7.
" lost	1.50	.75
Total	200.00	100.00

Test number XIV.—Hocking cannel coal, from upper member of No. 6 vein;

Coal charged into retorts, 200 pounds.

Total gas made, 856 feet.

Gas made per pound coal, 4.28 feet.

Candle feet obtained, 81.32.

	Pounds.	Per cent.
Weight of gas, (spec. grav., est., 500)	32.92	16.46
" coke	119.	59.50
" tar	9.	4.50
" liquor	20.	10.
" lost	19.08	9.54
Total	200.00	100.00

Test number XV.—Kanawha cannel coal, from Kanawha Valley (Cabin creek):

Weighs per bushel, 72 pounds.

Coal charged into retorts, 250 pounds.

Time carbonizing, 5.00 hours.

Produced 1st	hour,	350	cubic feet.	Candle	power	jet,	40.
2nd	"	331	"	"		"	24.
3d	"	281	"	"		"	16.
4th	"	248	"	"		"	12.
5th	"	70	"	"		"	7.

Yield of gas per pound of coal, 5.12 cubic feet.

Candle power (Bunson), 18.70; candle feet, 95.74 per pound.

Weight of coke, 163 lbs.

Coke, 3.75 bus.

Tar made, 3.50 galls. Breeze, .30 bus.

Inlet of condenser, 64°. Am'l liquor (5.50°), 1.50 gals.

Outlet of condenser, 62°. Atmosphere, 60°.

Scrubber, 62°. Barometer, 30.40°.

Meter, 62°.

Remarks.

Coke, produced per ton coal, carbonized,				33.60 bushels.
Breeze,	"	"	"	6.70 "
Tar,	"	"	"	31.36 galls.
Ammoniacal liquor, produced per ton coal, carbonized,				13.44 galls.
Coke,	"	"	"	1,590 lbs.
Gas,	"	"	"	11,468 cubic feet.

Test number XVI.—Hocking cannel coal, from upper member, No. 6 vein:

Coal charged into retorts, 200 pounds.

Total gas made, 917 feet.

Gas made per pound coal, 4.585 feet.

Candle feet obtained, 87.115.

	Pounds.	Per cent.
Weight of gas (spec. grav., est., 500)	35.26	17.63
" coke	114.	57.
" tar	11.	5.50
" liquor	20.	10.
" lost	19.74	9.87
Total	200.00	100.00

To show that the quantity of volatile combustible matter a coal contains does not indicate the quantity of permanent gas present, I append a table from the Ohio Report of 1870. The analyses were made by Prof. Wormley:

Volatile combustible matter.	Fixed gas—cubic feet per pound.
27.70	3.32
28.45	3.44
28.90	3.36
29.10	3.12
29.20	3.11
30.70	3.51
31.60	3.54
35.20	3.42
36.75	3.16
37.20	3.12
38.00	3.65
38.80	3.03
38.80	3.16
39.25	3.35

The Waterloo, or number 7 coal, gives the best analysis for the average of vein of any coal found in Wormley's reports.

This coal has not been tried in a gas-works, at least not from the fine field in Lawrence county. All things considered, the coal from Antiquity, near Pomeroy, Meigs county, number 8, or Pittsburgh seam, is the best for gas making of any that has yet been tried in the State. Fair yield, high illuminating power, easily purified and producing a good coke, these facts put this at the head of the list of Ohio gas coals.

A very general and superficial description of a gas-works plant will probably suffice for this volume. There has been no very marked change in apparatus used in gas-works during the last quarter of a century. The generating apparatus consists of retorts, now made of best fire-clay, formerly made of cast-iron. The retorts are usually about nine feet long by 14x24 inches inside measure, and generally (semi-

oval) shaped, though oval shapes are frequently used. The retorts are set in "benches" of three to eight retorts to a bench, three to five in small works and six to eight in larger works. The benches consist of brick arches or ovens, made large enough to contain the number of retorts desired to be used. Furnaces are built in the arches under the retorts. Dimensions of furnace are usually about 14 inches wide by three to four feet long and two feet deep. The retorts are closed at one end by being made solid. To the other end is attached a cast-iron "mouth-piece," and is closed by a cast or wrought iron lid, the mouth-piece having a circular opening of 4 inches to 8 inches, into which the ascension or stand-pipe is placed, which runs up in front of, and above the benches and by return bends passes down into the hydraulic main. The hydraulic main is usually made of cast-iron, shaped, and is filled with water to a point above the center line. The "dip-pipe" which is a continuation of the ascension pipe, dips down into the liquid in hydraulic main one-half to an inch in depth. A fire being made in the furnace, the retorts are heated up to 1500° or 2000° Fahr. Coal is thrown into the retorts and the lids luted on. Gas is immediately disengaged from the coal, passes out of the retorts up the ascension pipe, down the dip-pipes, bubbles through the water of the hydraulic main, and passes off by a pipe leading from the hydraulic main to condensers, scrubbers, purifiers, station meter, and on into the gas holder, where it is stored for use. To the hydraulic main is attached an overflow for the discharge of the tar and water generated from the coal. The scrubbers are large iron vessels filled with boards, boulders, coke, twigs of trees, or other scrubbing material, which arrests the tar and soot and other condensable matter and at least a portion of the scrubber or scrubbers will have water running through to absorb the ammonia. The condensers are a series of iron pipes surrounded by air or water or large vessels made similar to tubular boilers, air or water circulating through them, but kept from the gas by the divisions in the vessel. The condensers are expected to cool the gas down to a temperature ranging from 50° to 70° Fahr. The purifiers are large iron boxes filled with lime or some form of oxide of iron, through which gas is forced to percolate, and into which the impurities of the gas, sulphur and carbonic acid are deposited. The station meter registers the purified gas, which is then passed on to the holder for storage.

The gas-holder is made of light rolled iron, properly supported in-

side by angle and T iron and tie rods. The holder is simply a large tub or vessel, turned mouth down, and resting in the water of a large tank. The gas is conveyed from the station meter in pipes in under the tank and up through the water, and escapes above the surface of the water, but under the tub or holder, the pressure of the gas raising the holder, which is kept perpendicular by guide columns. Another pipe will lead from the inside of this holder to the streets and to the buildings to be lighted with gas; the weight of the holder giving the pressure necessary to force the gas to the burners of the consumer.

Many pieces of intricate machinery, such as exhausters, governors, pressure and vacuum gauges and pressure registers, etc., are left undescribed.

They are valuable and indispensable adjuncts to the *economical* manufacture of gas, but gas can be and is generated, purified, stored and distributed without their aid. The more notable improvements of the last few years, however, are the general substitution (not recent) of the clay for iron retort, enabling the manufacturer to run much higher heats; the various plans for dispensing with the dip or seal of hydraulic main; improved forms of washers and scrubbers; the general adoption of the iron processes for removing sulphur, instead of using lime; the general use of the exhauster to pump the gas from the retorts, and force it through the varied apparatus and into the holder. In some of the larger works, machinery operated by steam is used for drawing and charging retorts, instead of doing this work by hand. The adoption of these generative furnaces, by which the retorts are heated with gaseous fuel, is perhaps the most important improvement of recent years to gas manufacture. In the furnace described on a preceding page, coke is the fuel used, the coke being thrown into the furnace with shovels from the floor of the retort house.

There are several forms of the generative furnaces, and they are placed in various positions, but generally they are built in a basement constructed under the floor of retort house. The furnaces are made three to four feet long, twelve to twenty-four inches wide, and three to six feet deep. The hot coke is drawn from the retorts and descends into the furnace through a chute, which can be closed up air-tight. Sufficient air is admitted through the grate bars to consume the coke to carbonic oxide, which issues through the hot space above the coke up to the bottom of the retorts, a distance from three to six feet. Below the

bottom of the retorts the gas is mixed with air, heated either by the waste heat of the escape flues, or by having been kept in contact with the hot walls of the furnace and benches. Only sufficient air is admitted, as near as can be ascertained, to give the carbonic oxide gas another equivalent of oxygen burning it to carbonic acid, producing an intense heat and almost doubling the generative capacity of the bench of retorts. With the old style of furnaces, a retort of the size here described, will generate from good coal 5,000 to 7,000 feet of gas in twenty-four hours. With the generative furnaces the same retort will make from 9,000 to 12,000 feet of gas in the same number of hours.

In the retort house the gas manufacturer has three enemies to contend with, viz., stopped stand-pipes, carbon in retorts, and clinkers in the furnace.

The introduction of the generative furnace will rid him of the last mentioned trouble, but in doing so doubles the difficulty with the first, and adds to his tribulations by the second. It is generally believed that high heats are almost entirely the cause of the stoppage in stand-pipes, and the difficulty is created by the rapid generation of the volatile matter, both gaseous and liquid, and the rush of the vapor becomes too great for the capacity of the stand-pipe. We give it as our opinion that less tar passes through the ascension pipe in a given time in a retort heated to 2150° Fahr. than from one heated up to only 1500°, or 1800 Fahr.; that it is not tar that chokes up the stand-pipes, but free carbon; that the coal to be used must be experimented with to ascertain the best temperature at which to work that particular coal; and that it is possible not only to make rich gas at high temperatures, but that, up to a point at which the compounds composing coal tar are decomposed, but below the point at which free carbon is deposited the quality is improved. However, something more efficient than the stoker's eye must be made use of to determine the degree of heat carried in the bench, before gas men will be able to determine the proper degree of heat in the distillation of any particular gas coal.

The manufacture of gas for illumination being strictly a chemical manipulation, it may be of interest to briefly describe some of the chemical changes that occur in the apparatus of a gas plant from the time the coal is introduced into the retort until the purified gas is stored in the holder.

The coal is charged into the retorts, when those vessels are heated up to a temperature of not less than 1500° Fahr. and usually from

1800° to 2100° Fahr. The time the coal remains in the retort differs somewhat with the ideas of different engineers, and different character of coals. But it is the American practice usually to leave coal in the retorts four hours.

The volatile matter is driven off about as follows:

During	first hour, 35 per cent.		
"	second hour, 30 per cent.		
"	third	" 24	"
"	fourth	" 11	"

Most of the water is driven off during the first half-hour, and most of the tar during the first two hours. Whether the compounds of which the tar is composed are nearly all driven off during 1st and 2nd hour, or whether they continue to be evolved to near the end of the charge, but by reason of the higher temperature of the surrounding mass they are decomposed, and the carbon of the tar deposited as coke, soot and graphitic carbon, is a question that perhaps cannot be easily determined. At any rate the volatile matter passing out of the retort is composed of tar (in itself containing almost innumerable compounds), ammoniacal liquor of about 4 oz. strength, olefiant gas, light carburetted hydrogen, free hydrogen and in smaller volumes carbonic oxide, carbonic acid, sulphuretted hydrogen, oxygen and nitrogen. After the gas has left the retort, there are perhaps few chemical changes occur in passing through washers and scrubbers, until the purifiers are reached. Some depositions occur from change of temperature and change of velocity in the gas while passing through condensers, washers and scrubbers, and some chemical changes occur by the contact of free ammonia with sulphuretted hydrogen and carbonic acid, the result being the formation of the sulphate and carbonate of ammonia; both salts being soluble in water, are washed out in the washer or scrubber. Much stress is laid on the union of the two impurities named, by many gas engineers, more perhaps than the facts of the case warrant. There are usually four purifying boxes in a gas-works; three are in constant use, and one off for cleaning or for changing material.

It is the custom to pass gas through the three boxes at work until a test of the gas shows impurities passing the second box, when change is then made and the foulest or first box is thrown out of use. The second box becoming the first, the third the second, and the newly cleaned box becoming the third. If lime is used as the purifying agent,

it will be found on removing the cover from the foul box, that the free ammonia (especially if the lime used has been made very wet), will almost stifle the workmen, and yet the sulphuretted hydrogen and carbonic acid had been freely and profusely passing through that box. Their affinity for ammonia is apparently not great, and their union easily divorced. With lime as the purifying agent, the sulphuretted hydrogen is arrested and sulphide of calcium is formed; the carbonic acid is arrested, and carbonate of lime is formed. Bi-sulphide of carbon is supposed to be arrested by the sulphide of calcium. However, the almost intolerable stench of spent lime when used to arrest sulphur, and the first cost of lime, and the extra cost of labor in manipulating, have caused a general substitution of some of the forms of oxide of iron for removing sulphuretted hydrogen, which is really the most objectionable impurity that the gas manufacturer has to contend with. In most works lime is still used in a limited way to arrest carbonic acid, and in some the boxes are arranged so as to cause the gas first to pass through lime, then through oxide of iron. The chemical changes are supposed to be about as follows: The sulphuretted hydrogen is arrested in the lime boxes and soon fouls all three, if that is the number used. The first box arrests the carbonic acid, forming carbonate of lime, and the affinity of the lime being greater for carbonic acid than for sulphuretted hydrogen the latter is driven out of the first box into the second, after the saturation of the first box with carbonic acid, then that impurity attacks the second and drives the sulphur on the third, and from that on to the oxide of iron boxes. The advantage claimed for this system over passing gas through the iron first, is, that the lime fouled with sulphuretted hydrogen breaks up the bi-sulphide of carbon, which is not arrested when the process is reversed. In the oxide boxes there are no important chemical changes other than the decomposition of sulphuretted hydrogen and the formation of sulphide of iron. When the second box of a plant of four boxes of oxide begins to show traces of sulphuretted hydrogen passing, the foulest box is thrown out of the system and a clean one brought into use. On removing the cover of the oxide box the material is found to be quite black, and to heat rapidly on exposure to the atmosphere, and in some instances, when improperly treated, it has been known to ignite.

The heat is produced by the decomposition of the sulphide, the deposition of the sulphur, and the reoxidation of the iron. The color

of the oxide generally changes during revivification from black to red or brown. After exposure for twenty-four or thirty-six hours, or until the material has assumed its natural color, the oxide is again ready for use, and this process may be repeated over and over until the deposited sulphur will equal 40 to 50 per cent. of the bulk. No unpleasant smells are given off in manipulating the iron process, no sulphuretted hydrogen escapes when the material is exposed. There are several salts of ammonia and some of iron formed during the process, not here mentioned, they being of no particular interest to either the public or the gas manufacturer.

There are numerous inventions in use for the manufacture of gas from materials other than coal, as well as for using coal, only in part, the most prominent being that for the manufacture of "water-gas;" carbonic oxide and hydrogen being generated by the decomposition of steam, and this gas enriched by the use of the lighter oils obtained in refining petroleum.

But, as these works are not users of gas coal, and as it is not believed that any of these processes will materially affect the gas coal industry, they will not be further discussed here.

Some authors, in discussing the question of inferior gas made at or near the end of the charge, or when coal is nearly or quite coked, attribute the large per cent. of carbonic oxide that is then passed off with the gas, to vegetable (mineral) charcoal found in some coals. Others attribute it to leaky retorts with undue exhaustion, thereby drawing in the carbonic oxide from the furnace, the carbonic oxide resulting from the imperfect combustion in the furnace.

Both these positions seem untenable to the writer. With reference to the first, the vegetable charcoal cannot of itself give off carbonic oxide, and owing to the fact that all the water of the coal has passed off during the earlier stages of the distillation, there is less oxygen present to combine with the charcoal at the end of the charge than at the beginning. And if oxygen is present, vegetable charcoal is not necessary to the formation of carbonic oxide when an excess of carbon in form of coke is present. With reference to the second proposition, over-exhaustion does not occur any more at the end of a charge, particularly in large works, where fresh charges are being constantly introduced, than occurs at the beginning of the charge.

If, however, over-exhaustion did occur, and the furnace gases were drawn into the retort, it does not follow that because carbonic oxide is

found in the retort, that there was necessarily imperfect combustion in the furnace. The largest per cent. of the gas drawn in must be nitrogen, and if combustion in the furnace is perfect, the carbonic acid drawn into the retort and intermingling with the red hot coke would be mostly broken up into carbonic oxide. It is more probable that the carbonic oxide results from the reduction, or partial reduction of the metallic oxides of the ash, the highly heated condition of the coke at the end of the charge favoring such reduction.

The iron pyrites of the coal would be oxydized during the earlier stages of the decomposition by the water of the coal and by oxygen from other sources of the coal, sulphur escaping as sulphuretted hydrogen, and the iron becoming an anhydrous sesquioxide. During the last stages of the decomposition, the oxide of iron is reduced, possibly to the metallic state, but probably only to a protoxide, the oxygen forming first carbonic acid, which by contact with the highly heated coke is broken up into two volumes of carbonic oxide.

The carbonic acid of the lime in the ash is given off very slowly and mostly near the end of the charge, and it also is converted into carbonic oxide. The conditions near the end of the charge are favorable for the reduction of all the oxides of the ash. The various metals of the ash are not found reduced in the coke, from the simple fact that they are reoxydized when they are exposed to the atmosphere in being drawn from the retort. The principal oxides of the ash are silica and alumina. Whether the heat attained in a gas retort is sufficiently high to reduce these oxides with carbon is a little doubtful, though in the case of silica, not wholly improbable.

By the use of coal for manufacturing gas, valuable residuals are obtained. It would probably be nearer the truth to say that residuals are obtained, from which valuable compounds may be distilled or extracted. The most valuable of residuals is coke. Next in value comes coal tar, and lastly ammoniacal liquor.

The character and quantity of coke to be derived from coal, as before stated, enters largely into the question of its value to gas manufacturers.

There was probably not less than 135,000, and possibly 165,000 tons gas coke manufactured in the State of Ohio last year. Of this large quantity about one-half was used in the works, the remaining half being sold for use in cupolas, malt and green-houses, bakeries,

laundries, and for heating residences and places of business; the harder grades being usually crushed, and the more porous and lighter grades used as they come from the gas retorts.

The Ohio coals produce about 60 per cent. in coke of the weight of the coal charged. The best Youghiogheny and Kanawha coals produce from 65 to 72 per cent. of the weight of coal charged in retorts.

A simple analysis cannot determine the value of coal for gas purposes; for, as is shown in the instances referred to, the coal that sends off the largest volume of gas leaves behind in the retort the heaviest weight and best character of coke.

For many purposes gas coke, when cost and heat producing power are considered, is the most desirable fuel that can be obtained. It is light, weighing from 33 to 40 pounds to the bushel. Clean and free from the dust and smoke of our soft coals, and unlike oven coke, it does not require excessive draft to produce proper and rapid combustion. Containing nearly double the quantity of ash that coal contains, theoretically it should be inferior to coal. But when we consider that the volatile portion of coal, as the coal is burnt in the ordinary stove and grate, often furnishes but little more than enough heat for its own expulsion, and in fact carries off by expansion more units of heat than it produces, the value of gas coke as domestic fuel is then fully realized. While tar ranks second in value, when disposed of in the crude state, it is possible to extract from the tar of a ton of coal, compounds of a value far in excess of all other products—gas, coke and ammoniacal liquor.

The quality of coal tar is largely influenced by the temperature of the retort in which the coal is charged. A large volume might be written on coal tar and its compounds, but in this work it will only be possible to give a very general description of its characteristics and products obtained by its distillation. It is doubtful if it is possible for an analysis to be made of coal tar that will show the combination of the elements of which it is composed, as it flows from the retorts. An ultimate analysis would show chiefly carbon and hydrogen, yet the various compounds of these elements cannot be ascertained, as the very act of analysis itself destroys and changes their character. About one hundred and twenty different compounds are named as being found in tar. Coal distilled at a low temperature gives off tar in abundance, and the tar is rich in hydrocarbons of the paraffine series. But if the

retorts are highly heated the richer hydrocarbons, if formed at all, are broken up in the retort, some of the carbon taking the form of pitch, coke or graphite, and the hydrogen with a portion of the carbon, escaping in a gaseous state, probably as marsh gas. It is also quite probable that the tendency to break up the paraffine series is much greater under pressure than when free to escape as soon as generated, or when generated free from any pressure.

The quantity of tar to be derived from a ton of coal in gas-works varies largely, not only with the heats of the retorts, but much more with the character of coal. The Ohio coals, so far as we have been able to ascertain, give five to seven per cent.; best Youghiogheny, 2½ to 5 per cent., while some grades of Boghead cannel have yielded nearly 33 per cent. of tar, and the Leshmahago cannel, 20 to 25 per cent.

From coal tar is distilled benzole, creosote, naphtha, carbolic acid, anthracene, analine, alizarine, and numerous other products of great value in the mechanic arts and sciences. The last named compound, alizarine, or as it is sometimes called, artificial madder, was not known to be a constituent of coal tar until about 1869. At that time it would sell for $100 per ton. In two years time the demand had so increased that it was worth $2,500.00 per ton.

In 1879 it was estimated by competent authority that the aniline and alizarine dyes were manufactured from coal tar to the value of nearly $16,000,000.00, but none of it made in this country. And even at this late day the gas manufacturers of Ohio are, so far as the writer has been able to ascertain, making little or no effort to profit by the experience of their European confreres. It is doubtful if more than $60,000 to $75,000 is obtained per annum for all the gas tar made in the State, while at an expenditure of not to exceed $50,000 for plant, it is estimated by George Shepherd Page, of New York City (probably the ablest authority in this country on this subject), more than twice the profits might be had from the tar, and that without attempting to manufacture any of the more costly dyes.

In a paper read before the American Association of Gas Engineers, in October, 1880, Mr. Page gives an estimate of the comparatively crude products that may be obtained from the tar of 265,000 tons coal. The quantity of coal is so nearly the estimate of the quantity used per annum in the gas-works of the State that it is here presented:

2,400,000	gallons pitch.		1,000,000	gallons creosote oil.	
20,000	"	benzole.	20,000	"	naphtha.
20,000	"	blk. varnish.	22,500	"	carbolic acid.
3,333	"	carbolic acid crystals.	20,000	"	anthracine.
6,667	"	oil mybane.	2,777	"	creosote.
150,000	"	for use in tar-felting.			

The total value of the product is put at $367,500.00, of which $200,000.00 is of the coarser products, and $167,500 00 of the finer products.

The ammoniacal liquor of gas-works is produced by the distillation of coal in the heated retorts. A portion of it flows off as water from the overflow of the hydraulic main. This is seldom above what is called 4-oz. liquor, and frequently the strength is not more than 2-oz. The more valuable liquor is secured by washing or scrubbing, the water absorbing the gaseous forms of ammonia. By the use of properly constructed washers, it is easily enough to secure 16-oz. liquor. The strength may be increased up to 24-oz. without double washing or introducing the same water the second time. The total yield of ammonia varies greatly with the character of coal used, as will be observed by reference to tables given in preceding pages. Cannel coals are generally poor producers of ammonia. Some, in fact, are almost worthless to the distillers of ammoniacal liquor.

George Lunge, Ph.D., F.C.S., in his treatise on distillation of coal tar, presents the following table, showing the possible per centage of gas liqor to be obtained from a ton of coal.

The estimate is based on the per centage of nitrogen in the coal, and assumes that all the nitrogen should combine with hydrogen to form ammonia:

Origin of the coal.	Per centage of nitrogen.	Possible yield of N. H., 3 per cent.	Possible yield of gallons am. liquor 4° Twa. per ton coal.
Wales	0.91	1.10	142
Lancashire	1.25	1.52	196
Newcastle	1.32	1.60	206
Scotland	1.44	1.75	226

"Instead of this possible yield, rarely more than forty-five gallons of gas liquor of 4° Twaddle are obtained per ton of coal, usually only 25, and in London only thirteen gallons."

Ammonia is said to be present in gas liquor in the following forms: Free ammonia, ammonia carbonates, ammonium sulphide, sulpho-cyanide, acetates, chloride, sulphate, thiasulphate, and in other combinations in less quantity. The value of gas liquor is usually ascertained by the use of the hydrometer, each degree of Twaddle's hydrometer indicating two-ounce liquor. This system of estimating the value has been shown to be incorrect, as free ammonia will lower the density of water and the compounds increase the density in different degrees.

More attention has been given to the distillation of gas liquor by gas companies in this country than has been given to the distillation of their tar, and probably not one gas-works in twenty in the United States, certainly not in Ohio, derives any revenue from their gas liquor.

A very few of the companies of the State have sold their liquor to sulphate of ammonia manufacturers. The prices in the eastern States range from 20c. to 30c. per ton of coal carbonized. Prices do not range so high in the West. Probably at the present, with the depressed prices that rule for the distiller's product, not more than 25c. per ton of coal can be obtained for the gas liquor. But even this represents a large sum, say $50,000 to $60,000. But to make it possible to work up the production of the gas companies, there would need to be a concentration of the liquor at central points in the State. Now most of the gas-works produce too small a quantity to justify the erection of a plant.

In England, where fertilizers are in greater demand, and where, it is said, the standard of quality is much above the fertilizers manufactured in this country, almost every gas-works distills its own gas liquor and is able to obtain a revenue of 60c. to 75c. per ton of coal carbonized.

The following table gives the various gases and compounds in coal gas, and the per cent. of each by volume:

	Volume.
Hydrogen	48.70
Marsh gas	38.20
Olefiant gas	3.45
Carbonic oxide	7.92
" acid	.31
Nitrogen	1.00
Oxygen	.42
Total	100.00

The value of coal gas as an illuminant is enhanced or diminished as the per cent. of olefiant gas is increased or decreased.

With the generally reduced prices of gas, a very large consumption is now being caused by the use of gas cooking stoves and gas engines, and in this connection it will be of interest to give the heating power of the different gases, as found in the tables compiled by Dr. Letheby, leaving the non-combustible gases, nitrogen, oxygen and carbonic acid out of consideration :

1 cubic foot	of	hydrogen	gas	will elevate	1° Fahr.,	329	lbs. water.
1 "	"	marsh	"	"	"	996	"
1 "	"	olefiant	"	"	"	1,585	"
1 "	"	carb. oxide	"	"	"	320	"
1 "	"	common coal	"	"	"	650	"
1 "	"	cannel coal	"	"	"	760	"

CHAPTER XI.

THE GLACIAL BOUNDARY IN OHIO.

By Professor G. Frederick Wright.

The previous volumes of the Ohio State Geological Report have made large and interesting additions to glacial geology. No one can appreciate more fully than myself the value of the facts collected, and of the theories propounded upon the subject by Whittlesey, Newberry, Orton, Andrews, Winchell, Gilbert, Read, and others. My work in the State is simply supplementary to theirs. In setting forth the facts which I have brought to light, it will be in order, first, to present the general evidences relied upon to prove the glacial theory, which are:

1. The Scratches upon the Rocks.

The action of water in rolling gravel and sand loosely over exposed rocks polishes both the gravel and the rocks, but can do no more. In the northern part of the United States, however, the freshly exposed surfaces of rock have numerous parallel striæ running over them, and continuing across hard and soft portions alike. In some places these striæ extend for many feet, or even yards, and in size vary from the finest markings of a needle-point to grooves or furrows ploughed in the rocks, several inches in depth. My colleague, Professor A. A. Wright, describes a groove, on Kelley's Island, in hard limestone rock, known to be more than two hundred feet long, and from two to six feet deep.

The general parallelism of this striation demonstrates that it could not have been made by icebergs, though, as might be expected, the direction of the striæ varies greatly in different portions of the country. In the eastern part of New England the direction is considerably east of south. In the vicinity of the Connecticut and Hudson rivers the direction is south, while toward the western end of Lake Erie the striæ run west of south, though there is a set of striæ, even here, running at right angles. In general they may be said to radiate from a center situated near the south end of Hudson's Bay. The larger valleys modified the motion of the ice-stream somewhat; but usually the movement was continental,

and was undisturbed by ordinary hills, and at its height was not deflected in its upper portions even by low ranges of mountains. Upon the summits of the Green Mountains, in Vermont, and upon such isolated peaks as Monadnock, in New Hampshire, and Mounts Tom and Holyoke, in Massachusetts, the direction of the scratches is diagonal to that of the adjacent valleys. The ice-stream was no more disturbed by such obstacles than the moving water of a deep stream is by a pebble. Much of the exceptional variation in the direction of the striæ is probably due to the fact that the earlier striæ are erased by the later action of the ice. Doubtless the retreat of the ice-front was far from continuous, but there were successive oscillations, the ice often regaining ground from which it had withdrawn. Evidently, the markings left on the ice (except where specially protected), would be those made by the very last forward movement; and that naturally would be more influenced by local topography than previous movements would be when the ice was deeper. In Appendix I, will be found an Abstract of Glacial Striæ and Grooves in Ohio, prepared for me by Col. Charles Whittlesey. The comparative absence of observed striæ over a large portion of the State arises partly from the great depth of the overlying glacial deposit, described in the next section, and partly from the softness of certain strata, which, in consequence, do not retain the markings.

2. Ground Moraine, or Till.

A second evidence that the southerly movement of ice was glacial in its character, and not like that of icebergs, is to be found in the existence of a true "ground moraine" all over the northern part of the United States.

The material resting upon the striated surface of the rocks in that region is not a stratified water deposit, but coarse pebbles and the finest clay are indiscriminately packed in one mass. The enclosed pebbles also are scratched, the scratches upon them usually running parallel with their longest diameter, showing that the overlying mass was shoved along upon the rocks by an unyielding force. The stones that did the grooving were themselves striated in the process. This ground moraine, or "till," as it is technically called, closely corresponds to what accumulates under present glaciers, and is spread pretty generally over the whole glaciated region of America, though it varies greatly in depth in different localities. Sometimes the till is heaped up into hills,

two or three hundred feet high, as in the vicinity of Boston, and in Central New York. In other places, especially in Ohio and other western States, it forms a more uniform covering of considerable depth. By damming up old water-courses the irregular deposition of till has formed nearly all the smaller lakes of the country. In many cases these lakes, as well as the peat-bogs (so abundant over this region), are "kettle-holes," which, as Col. Whittlesey first suggested (see Smithsonian reports for 1866), were probably formed by the burial of great masses of ice beneath glacial *debris*. When in such situations the ice melted, depressions would be formed without any outlet.

3. The Terminal Moraine.

A third evidence of the existence of a glacier in North America, continental in its dimensions, is the sharpness and continuousness of the southern boundary of glacial phenomena, and the special accumulations of glaciated material along portions of this boundary. For a good portion of the distance, south of New England and westward to the Pennsylvania line, and at frequent intervals from there to Illinois, the accumulations at the border of the glaciated area are worthy of the name of *terminal moraine*. This terminal moraine consists of a line of hills varying from fifty to three hundred feet high, and composed chiefly of a compact, unstratified mixture of clay, sand, gravel and striated pebbles. Where the movement was over regions favorable to the incorporation of much earthy material, and where the conditions were such as to maintain the southern margin of the glacier a long time at a given point, large terminal accumulations would naturally result. The warm currents of air from the south here met the point of the slowly-advancing glacier, and for a long while held it at bay—melting back each summer as much as it had advanced during the winter. How extensive this terminal accumulation would be depends on a variety of causes. It would vary in amount at any particular point directly as the length of the period through which the ice rested on or oscillated over a given line, and also according to the amount of earthy material in that portion of the glacier whose motion terminated at the point. The amount of earthy material in the ice is determined by the nature of the rocks over which it was moved, and of the height of mountains past which it was led.

In various ways earthy material becomes incorporated into the ice of an advancing glacier. When the ice moves past an exposed precipice, fragments of rock fall down upon the ice, and landslides bring down from time to time a promiscuous mass of material. It is not improbable that the moving ice also breaks off projecting fragments of rock, and encloses them to be carried on by it in its onward motion. It is certain, also, that stones are picked up by the moving ice from the floor of the glacier, and by some process raised to a higher level. The ice being more or less plastic, and the stones unyielding, pebbles seem to work up in the moving mass as the larger marbles in a basket rise to the surface when the whole is shaken; or, since the upper strata of glacial ice move faster than the lower (owing to the effect of friction in retarding the movement at the bottom), the result is that the upper side of the boulder, which is embedded in the ice, is constantly subjected to a greater degree of onward pressure than the lower side. The effect of this must be to give an upward as well as an onward motion to the boulder in the ice. The course of such a boulder would be up a very gently inclined plane, the slower moving strata of ice beneath it forming the incline, and the more rapidly moving upper strata being the force to push it along. Once upon the surface, if the motion were to continue long enough, and the front were not too far away, the boulder might be transferred to the front, and deposited before the moving mass; and if the glacier were still advancing, it would stand a chance to be covered again with ice, and to be incorporated into the moving mass to repeat another cycle. But, whatever be the explanation, a great deal of earthy material was in and upon the continental ice-sheet, and moved with it southward. The effect would be to dump the material along the southern terminal line as the supporting ice was melted under it; and thus vast piles would accumulate. In many cases it can be demonstrated that boulders have been carried upon the back of the glacier hundreds of miles. There are hill tops in Western Pennsylvania and Southern Ohio completely covered with large granite boulders whose native place is far beyond Lake Erie, in the northern part of Upper Canada.

So far as I know, Pres. Edward Hitchcock was the first to intimate that if the glacial theory were true, the backbone of Cape Cod was a real terminal moraine (see Geol. Report Mass., Postscript); and I understand that Prof. Agassiz was accustomed in his lectures to speak

of it as such. Prof. Charles H. Hitchcock had also, as early as 1868, in an address before the Long Island Historical Society, advanced the theory that the line of hills marking the backbone of Long Island is a terminal moraine. Early in 1877, in a paper read before the Boston Society of Natural History, I was permitted to publish a personal communication from Clarence King, in which he declared with great confidence that the accumulations, in the neighborhood of Wood's Holl, and on the Elizabeth Islands, were a true terminal moraine. Mr. Warren Upham was the first to go over this whole field from the end of Cape Cod to Brooklyn, for the purpose of verifying the hypothesis. The results are published in volume III of the New Hampshire geological reports, pages 300–305, and in papers read and published in the American Journal of Science for August and September, 1879.

But upon all this the criticism could justly be made that the ocean was immediately beyond our boundary line, and that the absence of glaciation on the bottom of the sea could not be demonstrated. Profs. Cook and Smock had, however, a clear field, and in 1878 published the results of their investigation in New Jersey, and issued a map correctly and accurately showing the terminal moraine, as they prefer to call it, across that State. West of New Jersey there had been no continuous and accurate investigation of the boundary until 1881, when Prof. Lesley commissioned Prof. H. Carvill Lewis and myself to prosecute the work in Pennsylvania. Prof. Lewis and myself worked together in Pennsylvania during that summer, and will soon issue a joint report, though the responsibility of completing the explorations in that State has fallen wholly upon my colleague. We went, however, in company over about two-thirds of the whole line. In Ohio, Prof. Newberry, in volume II of the report of the Second Geological Survey of Ohio, had approximately outlined the boundary in that State, but in Ohio, as in Indiana and Illinois, the survey was necessarily carried on by a variety of persons, and before the most distinctive glacial marks were fully understood; hence, the uncertainty about the extent of the glaciated area in those States, and of a continuous and more minute exploration of the boundary line.

The extreme line of special accumulation appears, however, farther south than Cape Cod, first in Sankaty Head and Saul's Hills in Nantucket, on Tuckermuck Island, Chappaquiddick Island, and on Martha's Vineyard in the prominent hills extending southwest to Gay Head, reappearing again in No Man's Land, and in a remarkable knot of hills on Block Island. In Long Island it appears at Montauk Point,


MAP
OF THE
GLACIAL BOUNDARY
in
OHIO
BY
G. FREDERICK WRIGHT.
J.N.B. Del.
MICH.
LAKE ERIE
IND.
PENN.
WEST VA.
KY.
SCALE OF MILES
0 10 20 30 40 50

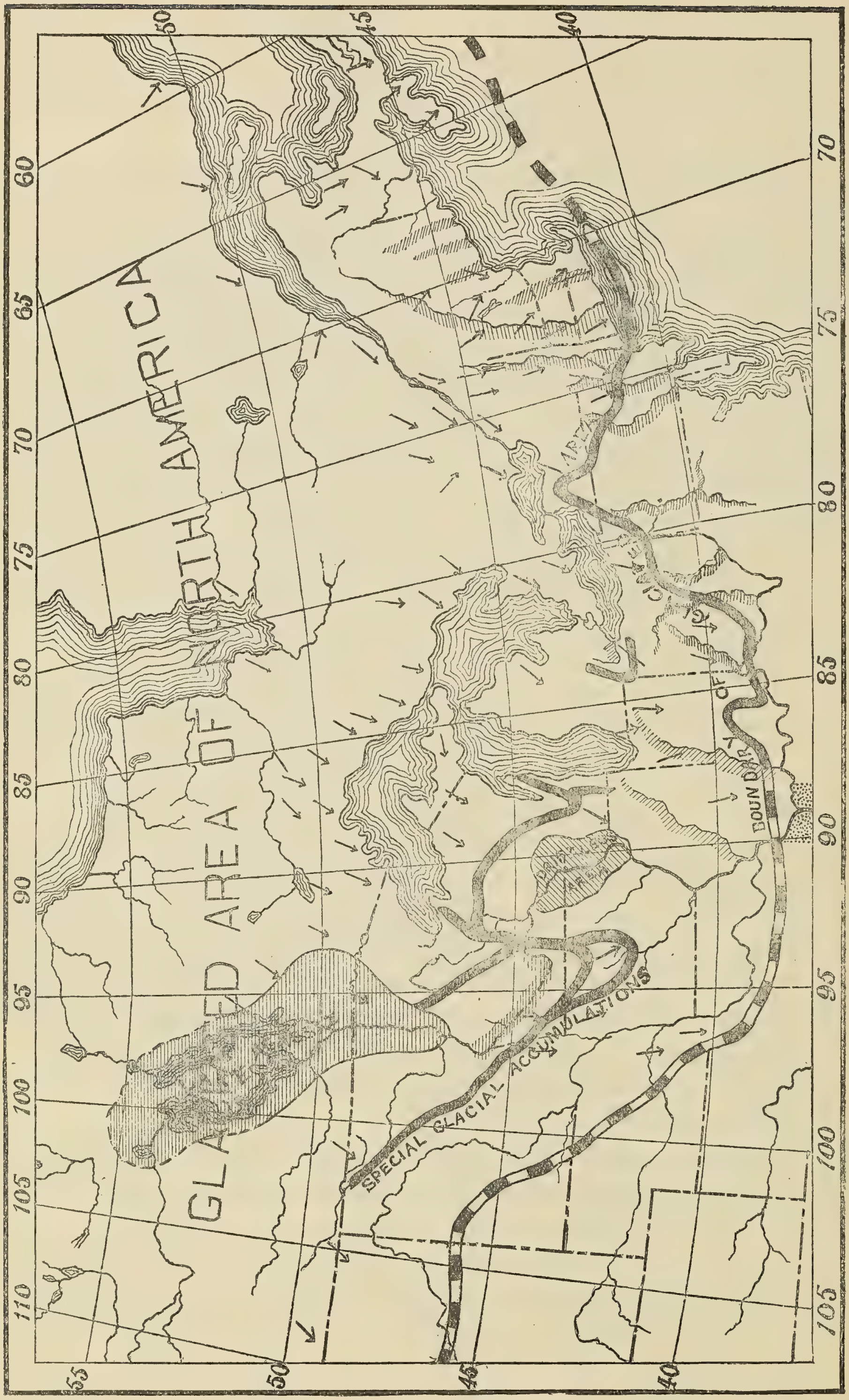
thence running to Sag Harbor and Canoe Place, and due west to Harbor Hill, at Rozlyn, the highest point in the island, thence west southwest through Greenwood Cemetery, Brooklyn, to the Narrows at Fort Hamilton and across the southeastern part of Staten Island.

About the same time (1876–77) Professors Cook and Smock, of New Jersey, accurately mapped the moraine across that State. Beginning at Perth Amboy, it bends northward through Raritan, Plainfield, Chatham, Morris, and Hanover to Rockaway, thence a little south of west to Belvidere, on the Delaware, a few miles above Easton.

From that point, leaving the Delaware at Belvidere, about fifteen miles above the mouth of the Lehigh, the glacial boundary crosses Northampton county by a general northwestern course to the centre of Monroe county. Here it turns westward, crossing the Lehigh at Hickory Run, about fifteen miles above Mauch Chunk, and continues westward until it crosses the east branch of the Susquehanna, at Beech Haven, about twenty miles below Wilkesbarre. Thence by a northwesterly course it continues through Columbia county, rising upon the summit of the Allegheny Mountains, and crossing them diagonally in Lycoming county; thence (still northwest) through Tioga and Potter counties into Cattaraugus county, New York, reaching its most northerly point at Little Valley, six miles north of Salamanca. Thence it runs in a pretty direct southwest course to Columbiana county, O.

The accompanying map of Ohio shows the glacial boundary explored by me during the summer of 1882. This does not, as some may have surmised, represent merely a line which I have traversed, but a line which I have zigzagged, and along which, I believe, I have determined with tolerable certainty the glacial boundary upon nearly every mile of its course. In every township I have endeavored to go far enough south of the line, here marked, to make it sure that I was beyond the limit of glaciation. Down to this line the marks of glaciation are everywhere abundant and unmistakable; south of it the absence of glacial marks is equally striking.

The glaciated area of Ohio consists of a rolling surface essentially like the prairies farther west, except that it was originally covered by timber. The preglacial channels have nearly all been buried out of sight, and it is rare that the rocks anywhere emerge above the till. The till itself contains everywhere glaciated fragments of a great variety of rocks, all of which are from the north. It is not unusual to find, in


AREA OF NORTH AMERICA
SPECIAL GLACIAL ACCUMULATIONS

the central part of the State, many feet below the surface, granite from Canada, Corniferous limestone, and fragments of sandstone, all striated, and intimately mixed together in the paste formed by the grinding up of the Ohio shales. Large granite boulders are thickly strewn all over the surface of this glaciated area. Some of the largest found in the State occur upon the very border of the glaciated region. A granitic boulder, found in Columbiana county, near Lisbon, is 13x11x8 feet out of ground. Another, near Lancaster, in Fairfield county, is 18x12x6 feet out of ground. Granite boulders from three to five feet in diameter are too numerous to mention.

The average depth of the glacial deposit over the area in Ohio, north of this boundary line, is estimated by Mr. E. W. Claypole (see Proceedings of A. A. A. S., vol. XXX, p. 151), to be fifty-six feet. No one at all familiar with the region will be disposed to think this estimate exaggerated.

The inexperienced observer will, however, frequently be confused by the evidence of water action in connection with the till. He should bear in mind that during certain seasons of the year large floods of water accompanied the glacier at all stages of its progress. Sometimes the water escaped by sub-glacial streams, at others by superficial streams; in all cases flowing towards the front, and making stratified deposits in places where there are now no streams, and which, while the glacier was advancing, might be covered by deposits of till. Again, as the glacier was retreating, there were vast floods from the melting ice, leaving terraces of coarse gravel in all the existing streams, as well as superficial deposits of sand and gravel in many places where no streams now exist.

The southern margin of the glaciated area of Ohio is not everywhere marked by such a relative excess of accumulation of glaciated material as is found through Cape Cod, on the Elizabeth Islands and Long Island, and at various places in New Jersey and Pennsylvania. The limit, however, everywhere is very sharply defined, and at various places, soon to be mentioned, in Stark, Holmes, Fairfield, and Ross counties, the marginal deposition is on a scale equal to anything which can be found in the south of New England.

The glacial limit enters Ohio from the east, in Columbiana county, at Achor, twelve miles north of the Ohio river, and continues nearly west to the middle of Stark county, where it turns more to the south,

crossing the northern part of Holmes county to the northeast corner of Knox, where it turns at right angles to the south, running through the eastern part of Knox and Licking counties, the western part of Perry, turning here so as to pass through Lancaster, in Fairfield county; touching the western edge of Hocking, and entering Ross at Adelphi, in the northeast corner. Here it turns to the west, crossing the Scioto Valley a few miles north of Chillicothe, and emerging from the county at its southwest corner, proceeding thence through the southeastern corner of Highland, the northwestern of Adams, reaching the Ohio river in the southern part of Brown county, near Ripley. Cincinnati was completely enveloped by ice during the glacial period, and extensive glacial deposits exist in the northern part of Campbell and Boone counties, Ky., and near Aurora, in Dearborn county, Ind.

In Indiana the line still continues to bear in a southerly direction through Ohio and Jefferson counties, grazing the edge of Kentucky again opposite Madison, and reaching its southernmost point near Charlestown, in Clarke county. From here it bears again to the north through Scott and Jackson counties to the line between Bartholomew and Brown, and follows this to the northeast corner of Brown. There again it turns to the southwest, touching the northeast corner of Monroe, where it again bears north for ten miles to near Martinsville in Morgan county. Here again the line turns west and south, passing diagonally through Owen, Green, Knox, and Gibson counties, and into Posey county as far as New Harmony, where for the present my investigations are broken off.

The following is a list of the counties and townships traversed by the glacial boundary in Ohio:

OHIO.

Columbiana County.—Middleton, Elk Run, Center, Hanover, West.

Stark County.—Paris, Osnaburg, Canton, southwest corner of Perry, Bethlehem, southern part of Sugar Creek.

Tuscarawas County.—Northwest corner of Wayne.

Holmes County.—Paint, Berlin, Hardy, Monroe, Knox, Ashland, southeastern corner of Hanover.

Knox County.—Jefferson, Union, Butler, Jackson.

Licking County.—Eden, Mary Ann, Newark, western border of Franklin and Bowling Green.

Perry County.—Thorn, western border of Reading.

FAIRFIELD COUNTY. –Southeastern corner of Richland, northwest corner of Rush Creek, southeast corner of Pleasant, northwest corner of Bern, Hocking, Madison.

HOCKING COUNTY.—Western border of Perry.

ROSS COUNTY.—Colerain, Green, Union, Twin, Paint, Paxton.

PIKE COUNTY.—Northwestern corner of Perry.

HIGHLAND COUNTY.—Brush Creek, Marshall, Jackson.

ADAMS COUNTY.—Northwest corner of Scott, Winchester, Wayne, northwest cor. of Liberty.

BROWN COUNTY.—Byrd, Union, Pleasant, Lewis.

CLERMONT COUNTY.—Franklin, Washington.

KENTUCKY.

CAMPBELL COUNTY.—Near the Pendleton county line.

KENTON COUNTY.—Northern part.

BOONE COUNTY.—Northern part, near Burlington, recrossing the river half way between Petersburg and Grant.

MORE SPECIAL ACCOUNT OF THE GLACIAL MARGIN.

Through Columbiana county, as in the adjoining counties of Pennsylvania, south of the heavy deposits of till, there is a fringe from one to three miles wide, over which there are scattered evidences of glacial action, consisting of granitic boulders and patches of till, here and there upon the highlands, at an elevation of from three hundred to five hundred feet above the Ohio river. North of this fringe the till is continuous and everywhere of great depth. At Palestine, on the eastern edge of the county, and at New Alexandria, near the western side, wells are reported in the till fifty feet deep. New Alexandria is upon the highest land in that part of the country, and the glacial deposits are marked in moderate degree by the knobs and kettle-holes characteristic of the moraine upon the south shore of New England. A mile or two west of Canton, in Stark county, the accumulations of glaciated material are upon a scale equal to anything upon Cape Cod. The northern part of Holmes county is covered with till, which is everywhere of great depth, and in numerous places near the margin, displays, though in a moderate degree, the familiar inequalities of the New England moraine. After the southern deflection, in Knox county, the glaciated region is entered near Danville, from the east, on the Columbus, Mount Vernon and Akron Railroad, through a cut in till, a quarter of a mile long, and from thirty to forty feet in depth. At the old village of Danville, near by, upon a neighboring hill, wells are reported as descending more than

a hundred feet before reaching the bottom of the till. Through Licking county, both north and south of Newark, the depth of the glacial envelope is great, up to a short distance of its eastern edge. At the reservoir, in Perry county, the distinct features of a moraine come out. The hill upon which Thornville is built is a mass of glaciated material in which wells descend from thirty to fifty feet without striking rock. This is upon the highest land of the vicinity.

The reservoir itself seems to be a great kettle-hole or moraine basin. All through Fairfield county, the glacial accumulation is of great depth down to a very short distance of its margin. But perhaps the most remarkable of all the portions of this line in Ohio is that running from Adelphi, in the northeast corner of Ross county, to the Scioto River. The accumulation at Adelphi, as shown where Salt Creek cuts through, is more than two hundred feet, and continues at this height for many miles westward. Riding along upon its uneven summit, one finds the surface strewn with granite boulders, and sees stretching off to the northwest the magnificent and fertile plains of Pickaway county, while close to the south of him, yet separated by a distinct interval, are the cliffs of Waverly sandstone, rising two hundred or three hundred feet higher, which here and onward to the south pretty closely approach the boundary of the glaciated region. Through the southeastern corner of Highland county and the northwestern of Adams, the terminal accumulation is less marked than in Ross county; still, the boundary of the glaciated region is easily determined. It approaches the river in the vicinity of Ripley, in Brown county, and crosses it from Clermont county, so as to enter Kentucky a half mile north of the line between Campbell and Pendleton counties. Cincinnati, as I have said, was covered with ice during a portion of the glacial period. There is an undoubted deposit of till at the railroad station at Walnut Hills, nearly four hundred feet above the river. At North Bend the tunnel of the Indianapolis, Cincinnati and La Fayette Railroad, leading from the Ohio to the Miami, is through an accumulation of till which rises 200 feet above the river.

I have given special attention to glacial terraces (see American Journal of Science, July, 1883), particularly at those points where streams pass from the glaciated into the unglaciated region. Here very generally there are extensive accumulations of coarse gravel and pebbles, such as naturally would be deposited in the last stages of the glacial

period when the ice was rapidly melting away and producing enormous floods. There were spring freshets to the glacial period of unprecedented extent, the marks of which in all these streams.

I append a list of streams with brief remarks :

LIST OF PLACES WHERE STREAMS EMERGE FROM THE GLACIATED REGION, WITH HEIGHTS AND CHARACTER OF TERRACES.

Middle Fork of Beaver, New Lisbon; terrace, 36 feet; material, coarse; pebbles, 10 to 15 inches in diameter, numerous; stratification, indistinct; contains kidney ore.

Big Sandy Creek, East Branch, East Rochester; extensive kame-like deposits, 30 feet high; material, coarse, diminishing in quantity and coarseness to Minerva, in Stark county.

Nimishillen, Canton. On east branch, terrace 41 feet above flood-plain; material, coarse and well rounded; pebbles, 16 inches, numerous. On the west branch, terrace rises in successive stages to 80 feet; surface, uneven. Two miles and one-half southwest a kame called "Buck Ridge" rises 85 feet above this terrace-plain. This is coarsely stratified, contains numerous granitic pebbles, and is characterized by a line of kettle-holes running to the northwest towards Akron. A mile south of the city two terraces, first, 38 feet above the bed of the stream; second, 36 feet higher.

Tuscarawas, Bolivar. Terrace in ox-bow, 51 feet; above the ox-bow, for a mile, 61 feet. Immense kame just north of the ox-bow, 154 feet above the river; material, coarse; contains boulders from 2½ to 3 feet in diameter.

Sugar Creek, Beech City. Extensive kames for several miles above Beech City; a mile and a half below Beech City gravel accumulation immense; knolls, ridges and kettle-holes abundant; terrace decreases in height and in coarseness of material down the river.

Killbuck, Millersburg. Five miles north, at Holmesville, gravel deposits two or three miles in diameter, about 25 feet above the flood-plain of the streams; kame running across it northwest by southeast, rising about 100 feet; material, rather fine; pebbles, rarely more than 3 inches in diameter. Half way between Holmesville and Millersburg, kame-like accumulation west side of the river, 50 feet. One mile and a half below Millersburg, west side, wide terrace, 102 feet above flood-plain. Two miles farther south, terrace 71 feet, level-topped, of much finer material. At Oxford, east side of the ox-bow, terrace 76 feet above flood-plain. Between Shimplin's Run and Black Creek, west of the Killbuck, terrace, 61 feet, fine material.

Mohican, northeast corner of Jefferson township, Knox county, terrace 107 feet above intervales; material, very coarse, extending up north at least a mile. At Gann's station, six miles below, large deposits of fine gravel.

Owl Creek, Millwood, terrace on tributary, from the north, 117 feet.

Rocky Fork, Wilkins' Run, Mary Ann township, Licking county; terrace, 92 feet, extends west to Madison township, merging there into till. Two miles east, extensive kames; material in all these rather fine.

Licking River, Newark; terrace at the cemetery, 108 feet, continues for more than a mile to the east. South of the city, terrace 60 feet +. The city is built upon a lower terrace, where three streams meet, several miles in circumference, 21 feet + above the stream.

Jonathan Creek, northern part of Thorn township, Perry county, head-waters separated from Licking Summit Reservoir by kames 15 feet to 30 feet high. Extensive gravel deposits down the stream east for two miles, flanked on each side by accumulations of peat.

Hocking River, Lancaster. The glacial outlet was not confined to the Hocking River, but was largely down a branch of Rush Creek, towards the east. This is filled with gravel, and dotted on the north side by gravel hills, 50 feet or 60 feet in height. North of Prospect Hill is a kamelike ridge of gravel about 100 feet high.

Clear Creek, Clearport, Madison township, Fairfield county, Muddy Prairie Run is made to join it here by a dtich. These streams rise in extensive swamps, and here pass through marked accumulatiens of gravel.

Salt Creek, Adelphi. Land slide exposes till, 180 feet; terraces extensive and very high below.

Scioto River, Green township, Ross county. Two miles east of the river, in the southern part, enormous kames, from 100 to 150 feet, running north and south; material rather fine, largely limestone. Three broad parallel ridges between this and the river, each one toward the river extending farther south. In Springfield township, two miles north of Chillicothe, terrace one-half mile wide, 48 feet above flood-plain.

Paint Creek, Twin township, Ross county; immense kames running north and south on Cat Tail Run; preglacial outlets in eastern part of township, completely filled up, compelling the river to make a new outlet to the southeast. (See Prof. Orton's Report, Ohio Survey, Vol. II., pp. 651–655; also paper of my own in American Journal of Science, July, 1883).

Perhaps the most interesting fact brought to light by these investigations relate to the extension of the ice across the Ohio river into Kentucky, where it left granite boulders and deposits of till upon the hilltops more than five hundred feet above the river. The glacial boundary first crosses the Ohio river twenty-five miles above Cincinnati, entering Kentucky, as already stated, near the southwestern corner of Campbell county, nearly opposite Pt. Pleasant, in Clermont county, O. Till, containing granite boulders and scratched stones, covers the hills in the vicinity of Carthage, Campbell county, and continues to a greater or less extent south along the ridge road as far as Flag's Spring. Here all signs of glaciation suddenly disappear. At Flag's Spring occurs an extensive deposit of water-worn pebbles which have been cemented together by lime. The pebbles are themselves mostly of lime. The deposit is in a valley tributary to Twelve Mile Creek (which runs to

the north), and rises from twenty to thirty feet above the present valley. It resembles in nearly every respect the post-glacial conglomerate, known as "Split Rock", at the mouth of Woolper Creek, about twenty-five miles below Cincinnati, where the glacial boundary recrosses the Ohio, and enters Indiana near Aurora. Whether there are granite pebbles in the conglomerate at Flag's Spring I am unable to say, owing to the haste with which I was compelled to examine it. But at Woolper Creek, granitic pebbles in small quantity form a constituent element of the conglomerate. One was observed which was two feet in diameter. The limestone pebbles in this conglomerate are frequently three or four feet in diameter. As pointed out forty years ago, by Prof. Locke, and noticed later by Dr. Sutton (see Indiana Geological Report for 1878, pp. 108–113), this conglomerate at Woolper Creek is not confined to the immediate vicinity of the Ohio; though there it rises more than one hundred feet above low-water mark. The conglomerate is conspicuously developed on the summit of the Kentucky hills for three or four miles southeast, and four hundred or five hundred feet above the river, and here, as at Flag's Spring, on the other side of Cincinnati, the formation marks the true glacial boundary. It would seem, however, that the ice nowhere extended into Kentucky more than four or five miles from the river. Near Burlington, in Boone county, on one of the tributaries to Gunpowder, which flows to the south, and whose source is between five hundred and six hundred feet above the river, there is a noticeable collection of granitic boulders marking the southern extent of the ice. Fifteen or twenty, from one to three feet in diameter, were counted in a small space. Three or four of these were composed of a metamorphic conglomerate containing jasper pebbles peculiar to the eastern shore of Lake Superior.

Prof. Lewis supposes (see Journal of Franklin Institute, April, 1883) that near Olean, in New York, where the ice extended for a short distance across the Allegheny river, a sub-glacial channel was kept open. It would scarcely seem possible that this was the case at Cincinnati; for the trough of the Ohio is considerably wider than that of the Upper Allegheny, and not far from fifty miles of the Ohio Valley bordering Campbell, Kenton, and Boone counties, Ky., must have been covered by glacial ice. Probably, for a short time, the ice at Cincinnati formed an obstruction to the channel; but what was the course of its overflow I am not prepared to say. The obstruction must have been

at least five hundred or six hundred feet in depth, this being the height of the watershed between the Licking river, in Kentucky, and the Ohio river on either side. Such an obstruction would set back the water of the Ohio far up into the valleys of the Allegheny and the Monongahela, submerging the site of Pittsburgh three hundred feet. (The low-water mark at Cincinnati is 441 feet above the sea, that of Pittsburgh, 715 feet). It remains to be seen how much light this may shed upon the terraces which mark the Ohio and the tributaries in Western Pennsylvania.

We learn from Prof. I. C. White, of the Pennsylvania Geological Survey, that the terraces of the Upper Monongahela correspond very closely in height to what we should expect if the ice-barrier at Cincinnati were such as I have supposed. In the vicinity of Morgantown, West Virginia, terraces of clay, sand, gravel, boulders, drifted logs, and other rubbish occur in the valley of the Monongahela up to an elevation of 1,065 feet, but above that elevation not a single rounded and transported boulder has ever been found. This corresponds very closely to the height of the barrier indicated by the glacial deposits south of Cincinnati. Similar terraces are found up the Allegheny and its tributaries to about the same height.

According to Mr. White, also, the glacial dam at Cincinnati presents a complete explanation for the origin of Teaze's valley, an ancient, deserted river channel, 20 miles long, and one to two miles wide, which leaves the great Kanawha 15 miles below Charleston, W. Va., at Scary, and passing through Putnam and Cabell counties, extends to the valley of Mud river, a tributary of the Guyandotte which empties into the Ohio at Huntington.

This valley, though having an elevation of 200 feet or more above the Kanawha, is filled to a great depth with rounded boulders of sandstone, chert, cannel coal, and other trash, which have been plainly transported down the Kanawha from above Charleston, so that although it was clearly seen that the water of the Kanawha had once found an outlet to the Ohio by the way of this valley and the Mud and Guyandotte rivers, yet why this ancient channel should have been abandoned for the present much more circuitous one had always remained a mystery until the key was furnished by the discovery of the great ice dam at Cincinnati; for it is now clear that while such a barrier would set back the water of the Kanawha until rising above the divide which had previously

separated it from Mud river, it sent an arm across to the Ohio by way of the Guyandotte, 50 miles below, where the other arm and main stream reached the same river at the present mouth of the Kanawha, thus converting portions of Putnam, Mason, and Cabell counties into a large triangular island, the base of which was formed by the swollen Ohio, and the sides by the two arms of the Great Kanawha. The melting away of the Cincinnati dam withdrew the water from the western or Mud-Guyandotte arm of the Kanawha, leaving the abandoned valley high and dry, but littered up with transported trash as we now see it, while the Kanawha continued on to the Ohio in its present and pre-glacial outlet.

A recent visit to Ashland, in Boyd county, Ky., revealed the fact that what had been reported as glacial deposits at that point closely correspond to those just described by Prof. White in the deserted river channel between the Kanawha and the Guyandotte. Through the kindness of Mr. John Campbell, of Ironton, O., and Mr. John Means, of Ashland, I was conducted over the ground, and it appears that all the way from Ashland to Greenup Court-house, and back from one to three miles from the river, on the Kentucky side, there is a deserted river valley about 220 feet above the present flood-plain. This level of 220 feet is very constant, and the hills rise on either side of it about 250 feet. When standing on one side of this old valley and looking across it, it is sometimes difficult to dispel the illusion that you are looking across the present valley of the Ohio. The valley goes by the name of "The Flat Woods," and may well be considered a continuation of the Kanawha-Guyandotte valley just described by Prof. White.

The deposits which had been attributed to glacial action, consist of numerous pebbles from a small size up to 18 inches in diameter, and occasionally one that is 2½ or 3 feet through. The material is uniformly quartz or flint; no granite pebbles are to be found, and all of it may well have been brought down the valley of the Kanawha by ordinary river action. No such pebbles are found upon the adjoining hills, and according to Mr. John Campbell, who is at once a competent observer and perfectly familiar with the region, nothing of the kind is to be found in Lawrence county, O.; thus demonstrating that this is entirely south of the glaciated area, and that the deposit is due in some manner to a former higher stage of river action.

The Unglaciated Area.

On passing into the unglaciated portion of the State, the whole surface of the country immediately changes its aspect: till suddenly ceases to occur; no scratched stones are to be found; granite boulders and other transported rocks disappear, except in the valleys of the streams. Over the whole of this unglaciated area the streams flow in narrow channels cut through the horizontal strata of the coal measures and of the Waverly sandstone to a depth of from three hundred to five hundred feet, and are everywhere lined by terraces of gravel which are far above the present high-water mark. The Ohio River, from far below Cincinnati to the head-waters of the Allegheny and Monongahela rivers, a distance of more than fifteen hundred miles, occupies a narrow valley worn by the stream in preglacial times, and was the great distributer of the drift brought into it by the streams from the north, which all along emerged during the glacial period from the ice-front, and which in some places approached to within a few miles of the river. Upon the highlands in this unglaciated region the soil is shallow, and consists of the remnants of the rocks in places which have been disintegrated by sub-aerial agencies.

As before remarked, in Ohio, and probably further west, the prairie region is seen to have been the product of the glacial period. It was the moving ice of that period which wore down the prominences and filled up the depressions to produce the dead level or gently rolling surface of all this prairie region. The action of running streams produces fertile intervals in narrow valleys, but the sheet of ice that passed over our continent ground up the rocks, and spread the detritus over the whole surface. In the glaciated regions of Ohio the soil is nearly everywhere fertile. A noticeable quality in the soil of this portion of the State is the mixture of the elements composing it. All the rocks to the north have contributed to its composition. In the soil of the glaciated counties there are found the pulverized fragments of various granites from Canada and of the local limestones, mingled with those of the neighboring shales and sandstones. All these elements have been kneaded together into one homogeneous mass by the moving ice, as the housewife kneads her flour and yeast together; and the fifty-six feet of till, to which we have referred, is as good soil at the bottom as at the top. The soil of the glaciated portion of Ohio is absolutely inexhaustible.

In extending the above remarks to the prairie region west of Ohio, they should be qualified by reference to the loess, which is a water deposit of varying depth, overlying the glacial gravels throughout a large portion of the Mississippi Valley. This probably indicates a depression of that valley, so as to form a great lake on whose bottom this sediment was deposited. From the position of this sediment overlying glaciated material, the subsidence of the region is known to have taken place since the ice withdrew. I know from personal observation that glacial material does underlie this loess throughout a considerable portion of Southwestern Indiana, and in Missouri, in the neighborhood of St. Louis.

It is evident that the ice movement of the glacial period pretty much made the most fertile portions of this State. It determined the character of the soil, the contour of the country, the minor lines of drainage, and thus in a thousand ways had to do with the pleasure, the health and the prosperity of the present and prospective population. As I marked off the glacial limits on a map of this State, the Secretary of the Board of Agriculture at once said that that was the southern boundary of the great wheat-producing portion of the State, and expressed an earnest desire that Ohio might secure as thorough an examination of the glacial phenomena within its bounds as has been done for New Jersey. Certainly, if one is to buy a farm in Ohio, he should pray that it be either in a river valley, or north of the terminal moraine. Of course, this statement must not be taken without qualifications; since, to this, as to all general rules, there are exceptions. There is as good land in the unglaciated portion as in the glaciated; but there is not so much of it in proportion, and upon the average it is not so good. The glaciated portion is nearly all first-class soil, and is almost boundless in depth. The contrast between the glaciated and the unglaciated areas of Ohio appears upon the pages of the Annual Crop Report. According to the report for September, 1882, the average production of wheat per acre in the glaciated area, reckoned by counties, is in many cases twice as great as in the unglaciated. The average production per acre in the whole glaciated area is about fourteen bushels, and in the unglaciated, nine bushels.

Miscellaneous Observations.

The abrupt changes in direction of the glacial boundary line merit a word of discussion. These are most manifest near Falmouth, on Long

Cod; Rockaway, in New Jersey; Salamanca, in New York; and in Ohio, near Canton; near the northeast corner of Knox county; near Lancaster; and at Adelphi. The map of Indiana likewise shows a remarkable bend to the north from the neighborhood of Louisville, making the glacial border sweep around a large, unglaciated triangle in the southern part of the State, of which the northern part of Brown county is the apex, the Ohio river from Louisville to Mount Vernon the base. These changes of direction are so abrupt as to cause much trouble in discovering the line. In searching for a cause of these sudden changes in direction, one soon finds, however, that they are not so difficult to explain as they seem. Ice behaves not like a solid, but like a semi-fluid. If an oblong block of ice be suspended upon the ends it will gradually sag in the middle. If a strong hollow sphere be filled with water, and a good-sized orifice be left through which the ice may escape, and the whole be subjected to intense cold, the ice will project through the hole for a considerable distance. As a matter of fact, ice flows like cold molasses or half-hardened lava.

It is not necessary to have a steep declivity in order to secure glacial motion. Ice can move in any broad valley where water would run. In our conceptions of glacial movement we are in danger of having our ideas cramped by the contemplation of Alpine glaciers. The demands made upon our imagination by the glacial phenomena of North America are, to some, almost staggering to reason. We are called upon to believe that along a line thousands of miles in extent the ice-front of the great glacier rested upon land which is nowhere much lower, and in many places is actually higher than the region from which it was dispersed. Boulders in many cases have been raised to a higher level than their native ledges.

Upon reflection, however, this is not so paradoxical nor so extravagant as at first glance it seems. It should be remembered that glacial ice is formed not by the freezing of water upon lakes and oceans, but by the accumulation of snow, which, under its own pressure, becomes converted into ice. If, now, over an extensive level surface, there should annually accumulate six feet more of snow than melted, 6,000 feet of ice would accumulate after a thousand years. It is thus easy to see that after a time the ice might form a mountain plateau by itself, and, owing to its semi-fluid character, it would gradually move along whatever lines presented the least resistance. Such accumulations about

the north pole would everywhere move to the south, and so we could get this southerly motion from the mere accumulation of ice, without supposing any change of level.

The influence of the Mississippi Valley would naturally favor the flow of ice in a southerly direction. But the slope from the Alleghénies to the Mississippi is gradual and tolerably uniform, and if the ice were simply adapting itself to the trough of the Mississippi, we should expect the curve of the southern boundary would be free from marked irregularities. The sudden deflections, southward, such as mark the line through Western Pennsylvania and Ohio, indicate another cause. The irregular southerly movement of ice would seem to have been due to irregularity in the accumulations of snow to the northward. For instance, if we suppose that the accumulation of ice over the State of Michigan and to the southward were a thousand feet in excess of that over Western New York and the Province of Ontario, that would produce a great extension of the ice-current south of Michigan. The forces from behind causing the ice movement would distribute themselves somewhat as in water when stones of unequal size are dropped into it at places not far distant from each other. The more vigorous waves, produced by the larger object, would project themselves a greater distance beyond the line joining the centers of disturbance than those from the other Where these waves met they would partially counteract each other. Such a meeting of forces evidently is indicated by the sudden southerly trend of the moraine in Knox county.

APPENDIX.

ABSTRACT OF THE BEARINGS OF GLACIAL STRIÆ AND GROOVES IN OHIO.

COMPILED BY COL. CHARLES WHITTLESEY.

NORTHEASTERN COUNTIES.

Ashtabula County.—No observations; the rocks principally shale.

Trumbull County.—Farmington township, S. 30° West; Vernon township, S. 20°, 30°, 40° East; Brookfield township, S. 50° East. Over the Pa. Line, Shenango Valley, S. 5° East; Fowler township, S. 4°, 30° and 45° East; Braceville township, S. 45° and 50° W.; Lordstown township, S. and S., 20° E.

Mahoning County Line.—Austintown, S. 30° and 35° East. Average of four exceptional observations, south and west, S. 31° W. Average of ten observations to the east of south, S. $22\frac{4}{10}$° E.

Geauga County.—Thompson, S. 50° East, and S. 40° and 50° W.; Hampden, S. 10° and 15° E.; Chardon, S. 10° E.; Chester, S. 50° and 70° E.; Russell, S. 50° and 70° E.; Bainbridge, S. 49° E.; Parkman, S. 30° W.

Lake County.—Leroy, S. 45° W.

Portage County.—Mantua, S. 30° and 40° E.; four observations, W. of S., mean, S. 41° W.; ten observations, E. of South, $37\frac{4}{10}$° E.

Cuyahoga County.—Solon, S. 45° E.; Euclid, S. 20° and 25° E.; Independence, S. 20° E.; average, S. $27\frac{1}{2}$° E.

Summit County.—Portage, near Akron, S. 10° to 35° E.; N. Hampton, S. 30° to 60° E.; N. Hampton, S. 30° to 35° E.; Middleburg, exceptional, East and West; Tallmadge, Coal Hill, S. 30°, 40° E.; Cuyahoga Falls, S. 45° E.; Twinsburg, S. 40° and 45° E.

Medina County.—Copley, S. 30° W.; Sharon, S. 40° E.

Wayne County.—Doylestown, N. and S.; average (not anomalous), S. $36\frac{6}{10}$° E.

WEST END OF LAKE ERIE.

Between Buffalo, at the east end of this lake, and the Islands, the rocks near the water level are generally too soft to retain the ancient ice-markings. On the lime rock at Buffalo there are numerous and distinct etchings that bear from south, 25° west to south 30° west, and run under water. Their bearings are nearly parallel with the axis of the trough of the Lake. At the mouth of Detroit River, near Gibraltar, the limestone beds are grooved and polished, and the bearings are also south 30° west. The islands and the limestone shores to the south and west are everywhere scored and grooved in the same way; but the bearing is generally more to the west,

differing, by nearly a right angle, with the general bearing in the northeastern counties.

KELLEY'S ISLAND AND SOUTHWARD.

Southeast corner, at water level, long grooves, S. 75° W.; Southeast corner, at water level, cross striæ, N. 80° W.; Calkins' quarry, north side, deep grooves, S. 80° W.; Calkins' quarry, north side, striæ, S. 70° W.; Calkins' quarry, water level, striæ, N. 80° W.; Calkins' quarry, water level, one heavy groove, S. 45° W.; Calkins' quarry, water level, one striæ, S. 60° W. Mean of twelve observations in different parts of the Island, S. 80° W.; West Sister Island, mean, S. 80° W.; Put-in bay, mean of twenty observations, S. 80° W.; Sandusky City, mean of four observations, S. 80° W.; Sandusky City, mean of two observations, S. 80° W.; Sandusky City, mean of one observation, S. 81° W.

Erie County.—Belleville, S. 75° W.; Belleville, S. 65° W.

Ottawa County.—Geneva, S. 65° W.

Lucas County.—Sylvanus, five observations, S. 50° W.; Monclova, four observations, S. 62° W.; Whitehouse, S. 50° W.; near Maumee river, seven observations, S. 62° W.

Wood County.—Portage, three observations, S. 50° W.; Otsego, three observations, S. 64° W.

Defiance County.—S. 45° W.

Paulding County.—Junction, three observations, S. 45° W.

Van Wert County.—Middle Point, two observations, S. 15° W.

Hancock County.—Findlay, three observations, S. 43° W.

Putnam County.—Blanchard, S. 20° W.; Sugar Creek, S. 50° W.

Auglaize County.—Auglaize, S. 48° W.

Seneca County.—Seneca, S. 5° E.; Seneca, S. 23° W.

Wyandot County.—Crawford, S. 20° W.; Crane, S. 5° W.; Marseilles, S. 10.° W.

Marion County.—Grand Prairie, north and south.

Miami County.—Troy, glaciated surfaces, bearings not given.

Highland County.—New Lexington. According to Professor Orton, very marked *roches moutonnees.* Dr. John Locke, in the Second Report of the First Geological Survey, 1838, p. 230, has given a *fac simile* of polished limestone from Light's quarry, near Dayton, Montgomery county. It was done by placing a scored block in a ruling machine, by which it engraved itself to perfection. The grooves are from $\frac{1}{40}$ to $\frac{1}{8}$ of an inch deep, and from a line to $\frac{3}{4}$ of an inch wide. Both the grooves and the finer striæ are in groups, or fascicles, as high as 10 in number. They were perfectly straight, and covered by two feet of earth. The average bearing is about S. 26° E., ranging from 19° to 21°, 31°, and 33°; but tbe greater number of the most pronounced are S. 26° E.

The above abstract is compiled from the observations of Professors Newberry, Read, Winchell, and Gilbert, of the Second Ohio Survey, and from those of Col. Whittlesey. Most of the irregular and exceptional bearings can be accounted for by the local topography turning aside the general movement. The highest elevations are 625 to 650

feet above the lake, above which the ice-sheet must have risen several hundred feet.

GLACIATED AREA OF NORTH AMERICA.

We have inserted on page 756 a map of a portion of the glaciated area of North America. The arrows indicate the direction of glacial striæ, as collected by Prof. Chas. H. Hitchcock, from various geological sources. The portion of the boundary of the glaciated area consisting of broken lines is hypothetical; the rest has been accurately determined as described in the text. The special glacial accumulations indicated by the broad lines in the interior belong to what Professor Chamberlin calls the "Kettle Moraine" (see Geological Reports of Wisconsin and Minnesota.) The dark line southwest of Lake Erie represents the supposed moraine of a Lake Erie glacier described on page 50, volume II, of this report.

The shaded area, marked "Lake Agassiz," is supposed by Minnesota geologists to be the bottom of an immense glacial lake which existed so long as the ice dammed up the northern outlets to that region. The shading upon the rivers indicates the terraces which characterize all streams connected with the glaciated area. In New England the shading is seen to be independent of streams where it represents kames, which are gravel accumulations connected with the close of the glacial period, and corresponding in many respects to terraces in character, but independent of water-courses. (For fuller description see the sixth chapter of my "Studies in Science and Religion." Andover: W. F. Draper.)

NOTE.—I regret very much that through a misunderstanding one form of Professor Wright's report was sent to press before his corrected proof had been received. When the proof came to hand, the press was stopped and corrections were made, as far as practicable, but one half of the edition had been already printed. The result is that a number of minor errors will be found on pages 753–768, inclusive, in part of the volumes. They are not, however, deemed sufficiently important to require a special table of *errata*. E. O.

CHAPTER XII.

THE COAL SEAMS OF THE LOWER COAL MEASURES OF OHIO—Continued.

THE MASSILLON COAL FIELD.

By Edward Orton.

Under the designation of the Massillon Coal Field, the most important mines of the Sharon coal (Coal No. 1), at present known in the State, will be considered. The field occupies adjacent portions of Summit, Medina, Wayne, and Stark counties. It extends from Tallmadge, Akron, and Wadsworth, on the north, nearly to the south line of Stark county. The coal of this seam is mined, or has been mined in the townships of Tallmadge, Springfield, Coventry, Franklin, Norton, and Copley, of Summit county; in Wadsworth township, of Medina county; in Chippewa and Baughman townships, of Wayne county; and in Lawrence, Jackson, Tuscarawas, Perry, Sugar Creek, and Bethlehem townships, of Stark county. A line can be drawn connecting the several mines that are, respectively, furthest north, east, south, and west within the area where this coal has been worked, and the space thus enclosed might be called a map of the Massillon Coal Field, but such a map would not answer for all of the purposes for which maps are made. Drill-holes and trial pits, sunk afterwards, would be quite likely to show basins of the coal in question, outside of the boundary, and they would not, by any means, be certain to show its presence at all points within the line. The reasons for this inadequacy are as follows: Much of the territory is drift-covered, and sharp boundaries of the underlying geological formations cannot be drawn. In the next place, most of the coal is below drainage. Finally and chiefly, the original deposits of the coal were exceedingly irregular, never covering but a small fraction of the area included in such a boundary line. In the accompanying map, which is entitled *Map of the Massillon Coal Field,* the

locations of the principal mines are shown, but no symbols are ventured upon to indicate the extent and reach of the field. The map is based upon one prepared a number of years since by Mr. James Nicholls, mining engineer, for Dr. Newberry, to accompany a volume in course of preparation. In the accounts that follow of the several mining centers, the facts that are at hand bearing upon these questions will find place.

Newberry has given a good account of the field in his report upon Summit county, vol. I, page 214, *et seq.*, and in his report upon Stark county, vol. III, pages 156–167, and also in his general discussions of the lowest coal. A knowledge of these previous statements will be presupposed in the descriptions that here find place.

That this seam is really at the Sharon horizon (Newberry's Coal No. 1), is established on the surest foundation. Every fact that can have a bearing on the question is in harmony with this view. The sections above and below are in exact accordance. Below lies the Sharon conglomerate, which is, however, a very uncertain element, being frequently replaced by sandstones and shales, without a pebble. Under the Conglomerate is the Waverly group, consisting of the Cuyahoga shales, the Berea shale, Berea grit and Bedford shale. All these are found in outcrop, and also in borings in due order, on every hand.

The coal itself, in its mode of accumulation, and in its present disposition, agrees exactly with the Mahoning Valley coal. In physical properties the coal of the two fields differs somewhat, it is true, but no more than the most strictly continuous seams of the entire series will differ when traced through an equal extent of territory. The Massillon coal is in a great number of instances covered by a few feet of black shale; this is, in fact, the normal cover, and this slate is charged with the fossils that are characteristic of the seam elsewhere. Above the slate come the Sharon shales with their nodules of iron ore. These shales are very largely worked in Summit county for the manufacture of sewer pipe, and the character of the horizon is thus perfectly understood. The little "rider" seam of coal also comes into the sections frequently, 30 to 50 feet above the main coal. It is nowhere large enough to be mined, but there is no reason to doubt that it represents the Quakertown coal of the Mahoning Valley, which is Newbery's Coal No. 2. Still higher comes the Massillon sandstone, and above it, at the proper interval, the Mercer Group, the clearest and most unmistakable series of the Lower Coal Measures.

1. Structure of the Massillon Coal Field.

As is the case with the Sharon coal seam elsewhere in Ohio, the coal of the Massillon field is in all cases disposed in distinct basins or troughs, which range in size from a few acres up to a few hundred, but rarely exceeding two hundred acres; the greater number range between 30 and 70 acres. Each basin or trough holds a lenticular body of coal, the thickest part of which is generally at the center or along the axis of the basin, and which is known among the miners as the "swamp" of the seam. Toward the margins of the basins, the coal grows thin, sometimes gradually, and sometimes by rapid reduction in volume. As the seam is seldom followed by the miner when it runs below 2 feet in thickness, it is quite possible that some of the basins that appear to be distinct may in reality be connected through a thin sheet of coal that stretches over the "hills" of the mines. These basins are frequently grouped in close proximity, to the extent of a half dozen or more, but some appear to be separated by wide intervals from any other bodies of coal.

There is apparently a normal or regular thickness of the seam, for the swamps of all the important basins generally show about 5 feet of coal. The better mines yield about 4,500 tons to the acre by the present system of working.

The coal of the several basins is laid upon an uneven floor, and considerable differences of level are due to this fact, but in addition to this, the basins as a whole share in the inclination of the whole series of rocks in which they are included. In general terms, the dip of the coal may be said to be to the southeast, but there are many local exceptions to this statement. The margin of the Coal Measures is a sinuous one, and this fact is not altogether due to the accidents of atmospheric waste and erosion, but it seems to go back to original conditions of deposit. The dip of the coal basins adjusts itself in part to this margin, being generally at right angles to it, but in the large way all of them incline to the south and southeast.

The facts of the dip can be learned from an examination of the accompanying chart, which was prepared by Mr. James Nichols, under Dr. Newberry's direction. It is entitled *Map showing Elevations of Massillon Coal, etc.*

The elevations of the coal are also shown herewith in tabular arrangement, to facilitate reference.

Beginning at the Akron mines, we find the following series:

	Above Lake Erie.
Coal of Brewster Bros. mine, Shaft	493.7 and 490 ft.
" " " mine, Drift	483.5
" Middlebury Shaft	464
" Brewster Slope	409
" Steese mine—Drift	419
" Johnson mine	419.3
" Franklin mine	421.8
" Krouse mine	391.7
" Chippewa mine	468
" Lester mine	448
" Fulton Slope	384
" Barney McGue's mine	388.9
" Crawford Slope	338.3
" Ground Hog mine	349.6
" Aberdare mine	334.5
" Mountain mine	318.5
" Willow Bank mine, No. 1	342.5
" Brookfield mine	341.2
" Grove mine	316
" Warmington mine	337
" Pigeon Run mine	322

The levels of the canal are also given to furnish a basis for comparison of other elements with those above enumerated:

	Above Lake Erie.
Summit level	396.66
Level from Wolf Creek to Clinton	387.66
" Clinton to Fulton	372.66
" Fulton to Massillon	366.66

In dealing with these figures, it is necessary to bear in mind that the elevations of the coal in different parts of the same mine have a play of 20 to 50 feet, irrespective of any general dip. The descent is often made very abruptly. This fact will remove some of the anomalies in the previous table.

From the northernmost station, which is the Middlebury mine, to Krouse's mine, sect. 22, Franklin township, there is a descent of 72.3 ft. The distance is 10 miles, and the direction is nearly southwest. This shows the fall in this line to be 7 ft. per mile. But from the same station to the Franklin mine there is a descent of only 42.2 feet in 8½ miles. This reduces the dip in the same general line to 5 ft. per mile. The latter figure is the more reliable, as a number of elevations agree with that of Franklin.

From the Krouse mine to the Chippewa mine, the distance is $5\frac{1}{2}$ miles, and the direction is southwest as before, but the coal rises in this interval 76.3 ft. The Franklin coal is but 46.2 ft. lower than the Chippewa coal. The dip from Chippewa to Franklin is about $6\frac{1}{2}$ feet per mile. Chippewa and Middlebury coals being at the same level, the line that connects them may well enough be taken as the line of strike or level bearing. This agrees fairly well with the general facts of the dip in this region.

To ascertain the strongest dip, the elevations of the Chippewa mine, 468 feet, and of the Mountain mine, 318.5 feet, and also of Willow Bank, No. 1, 342.5 feet, can be compared. The distance is about $7\frac{1}{2}$ miles. The direction from the Chippewa to the Mountain mine is nearly southeast, and the descent is 147.5 feet, or about 20 feet per mile, but to the Willow Bank coal, which is west of the Mountain, the fall is only 125 feet, or about 16 feet to the mile. From the Lester mine, which is near the Chippewa, but which holds a lower level (448), the fall to the Mountain mine is at the rate of 17 feet per mile, and to the Willow Bank, about 14 feet per mile. The most southerly mines that appear in the list, as the Grove, Warmington, and Pigeon Run, we find to the west of the main line of dip, above noted, and lying nearly level on a north and south line with the mines nearest Massillon. It is seen from these comparisons and from such others as the figures of the preceding table render possible, that while the dip is not nearly enough uniform in any direction to warrant its employment in determining the position of the coal at new stations, still no great anomalies are found, and, least of all, does it tend to high figures.

2. Character of the Massillon Coal.

The Massillon coal is an open-burning coal, containing an average of about $53\frac{1}{2}$ per cent. of fixed carbon, 37 per cent. of volatile combustible matter, $5\frac{1}{2}$ per cent. of moisture, and 4 per cent. of ash. The fixed carbon ranges from 50 to 57 per cent. The volatile combustible matter is quite uniform, seldom rising above 38, nor falling below 35 per cent. The moisture has not been found lower than $4\frac{1}{2}$, nor higher than $6\frac{1}{4}$ per cent. A wider range is shown in the ash, the limits of the analyses made for the Survey being respectively 1.6 and 6.3 per cent. The percentage of sulphur is about 1.1. These figures evidently show one of the very best coals of the State. As will be hereafter seen,

there are some large basins that fall a little below the standard in quality. It is an open-burning coal, but not of the same character as the Mahoning Valley seam. From the latter it is distinguished by its larger proportion of bituminous matter as shown by its burning with a longer flame. It is also a brighter coal, holding much less mineral charcoal. Its open-burning character is, however, pronounced, and it has long been used successfully in the blast-furnace as a smelting fuel. It is the dryer or splintier portion of the seam that is turned to this use. It is well faced, so far as the main joints are concerned, but the end joints or "cutters" are very close and tight. This fact has led to a system of mining different from any that is elsewhere followed in the State. The coal is blasted without being undermined, and sometimes without being "sheared," or, in mining phrase, it is "shot out of the solid". The undermining can well enough be dispensed with, but the shearing or cutting of the coal is essential to good mining. More powder is required to the ton of coal in this field than in any other in Ohio. The most coal that can be expected from a keg of powder is 35 tons, and the amount is sometimes reduced to 20 tons. At these rates, the cost of powder to the miner ranges between 9 and 16 cents for each ton of coal.

Royalty ranges between 15 and 30 cents per ton, and is paid on lump or round coal in nearly all cases at the present time. Screens are in universal use for cleaning the coal. The standard commonly recognized, is 12 feet by 5 feet, with a mesh of $1\frac{1}{8}$ to $1\frac{1}{4}$ inches, but this last element has some range. It never falls below the standard, but often overruns. The amount that goes through the screens differs in different mines. Generally from $\frac{1}{3}$ to $\frac{1}{5}$ of what is sent out in the bank cars is found below the screens. Of this amount about half, sometimes more and sometimes less, is nut coal. South of Massillon the output is divided thus: one car of nut to 9 of lump; one of slack to 7 of lump. The nut derived from the curly coal is more valuable than that from the splinty coal, the former selling at the mine about 40 cents, and the latter about 65 cents below the lump coal. In the city markets, these distinctions are apt to vanish, and the price of both grades comes within 25 cents of the lump coal. Within the last few years a market has been made for the slack also. The entire product of the mines now goes forward. Throughout the field, the face of the coal is often encrusted with a thin film of carbonate of lime, which is commonly

known as white cap. As to its effect upon the strength of the coal, there is a difference of opinion. In some mines it is held to reduce the strength of the coal, causing the seam to yield more nut and slack. In others it is claimed that the coal is cemented at the joints by this means and is thus enabled to bear handling with less loss. It is quite a distinctive mark of the coal in the lake markets, but it is not limited to this seam as is popularly held.

The usual price of mining is 85 cents per ton, with an allowance of 4 cents for every 3 inches below 4 feet. The miner makes from 2 to 4 tons per day of clean coal.

3. Uses of the Massillon Coal.

A coal of the character already described is seen to be adapted to almost all of the important uses to which bituminous coals are put. It is an approved furnace and mill coal, and a steam coal of high grade, but for household use it is so happily adapted that not only is it the standard in this respect in the markets that it reaches, but a constantly increasing per centage of it is being turned to this service. The proportion now used as domestic coal is variously estimated at 60 to 80 per cent. Its adaptations to household use have been already pointed out (page 150). It is to be regretted that any large amounts of a coal of such high grade, and which exists in such limited quantity, should be used up in the manufacture of steam in locomotive and stationary engines, for which far inferior qualities are available, but this result follows necessarily from the present state of the coal market, and a considerable amount of the comparatively small acreage left of this famous field is annually turned to these inferior uses. But little of it is used in blast-furnaces at the present time.

4. Mines of the Massillon Coal Field.

A brief account of the chief centers of present production and of many of the leading mines of the field will now be given.

a. Mines of Tallmadge Township.

The coal of this township was the first coal mined for the northern market in the State. A considerable acreage has already been exhausted. Mr. Philip Thomas has leased all the known remnants, aggregating possibly 20 acres. A new tract on his own land has lately been proved

to hold the coal. But two mines are now worked, and these in a small way, producing from 30 to 60 tons a day, mainly to meet the local demand. The coal averages 4 feet in thickness, where worked. The direction of the faces or main joints is N. 35° E. A considerable proportion of the product is red or weathered coal. The quality of the coal that is left is not equal in all respects to that of the larger deposits.

Its average composition can be seen by the following analysis (sampled by F. Keffer) :

Analysis of Tallmadge Coal (Lord).

Moisture	5.33
Volatile combustible matter	37.92
Fixed carbon	51.40
Ash	5.35
Total	100.00
Sulphur	1.85

b. Akron District, Springfield and Coventry Township.

The Middlebury shaft, operated by Payne, Newton & Co., of Cleveland, is one of the largest and best known mines of the district. Its average daily output is about 200 tons. The coal exists as an undivided seam, with a maximum thickness of 5 feet. It is worked down to $2\frac{1}{2}$ feet. The average of the worked areas is $4\frac{1}{4}$ feet. About 200 acres have been mined out, and the acreage tributary to the mine will soon be exhausted. The roof is black slate or sandstone, and the two elements occur in nearly equal proportion. The shale is, of course, the more desirable cover. The largest use of the coal is for house fuel, but it is also used in generating steam, and to a small extent as a furnace coal.

The average composition is shown in the following analysis (sampled by F. Keffer) :

Analysis of Middlebury Shaft Coal (Lord).

Moisture	4.72
Volatile combustible matter	38.10
Fixed carbon	52.78
Ash	4.40
Total	100.00
Sulphur	0.88

The Brewster Brothers' Slope was a mine in the same basin with the mine last described. It was exhausted in 1882. In thickness and quality of the coal, it agreed entirely with the Middlebury shaft.

The Thomas Brothers' mine, otherwise known as the New York mine and the Old Sumner mine, is in an adjacent tract, originally including about 15 to 20 acres of coal, now verging to exhaustion.

The coal of this mine is mined without powder. It is mainly "crop coal," and is consequently weaker and freer in the joints than the rest of the seam, resembling the Mahoning Valley coal more than elsewhere. It mines small, and is used exclusively by the Middlebury potteries.

The mine of the Brewster Coal Company, in Coventry township, has but a few thousand tons of coal left at best, and this mainly crop coal of inferior quality. The mine is a continuation of Brewster Brothers' Slope, already noticed. The face of the coal is N. 50° E. The seam runs as high as 6 feet in some of the swamps, but it averages about 4 feet. It is not generally worked below 2½ feet. This coal finds its way to Lake markets exclusively.

On the line dividing the Brewster Brothers' coal property from the Brewster Coal Company's land, a deep hole was drilled in 1882, the depth of which was about 800 feet, at the time that the following record was obtained:

Drift-clay and sand	27⅓	feet
Sharon coal	4½	"
Fire clay	4	"
Sharon Conglomerate	178	"
Cuyahoga Shales—blue	170	"
Berea Grit	48	"
Bedford Shale, followed by Cleveland and Erie Shales—blue	368	"

The identifications are made by the Survey, but they will scarcely be called in question by any geologist, corresponding as they do with the sections of the outcrops everywhere. The conglomerate has an excessive thickness, but this formation has no normal measurement.

The Lake View mine is one of the larger mines of this section, its daily output being 225 to 250 tons. It is operated by the Lake View Mining Company (Todd, Stambaugh & Co., of Youngstown). It is connected with the Valley Railway by a branch line.

On the land of Charles Switzer, which holds part of the coal of this mine, the following section is found:

1.	Drift	2.0 feet.
2.	Yellow sand rock	14.0 "
3.	Brown "	3.0 "
4.	Yellow "	2.0 "
5.	Coal	0.1 "
6.	Blue shale	2.0 "
7.	Brown sand rock	3.0 "
8.	Yellow sand rock	18.5 "
9.	Light shale	2.0 "
10.	Blue fire stone	2.0 "
11.	White sand rock	9.0 "
12.	Brown sand rock	3.6 "
13.	Rocky shale	10.0 "
14.	Black slate	2.6 "
15.	Coal	5.0 "

The upper coal, No. 5, of the section, is the representative of the Quakertown seam (coal No. 2), occurring here about 60 feet above the Sharon coal. Both divisions of the Connoquennessing or Massillon sandstone are seen in this section. This represents fairly this immediate district.

The coal appears to good advantage in the Lake View mine. It yields only one-fourth of nut and slack, the slack exceeding the nut in the proportion of 3 to 1. Sulphur runs low in most portions of the coal, but there are parts of the mine where it becomes excessive. The face of the coal runs N. 25° E. Its mean thickness is 4 ft. 6 inches. The coal is partially cut out by intrusive sand rock and shale in many places, but the normal cover of black slate is generally present.

The average composition of the Lake View coal is shown in the following analysis (sampled by F. Keffer):

Coal of Lake View Mine (Lord).

Moisture	5.15
Volatile combustible matter	40.67
Fixed carbon	52.00
Ash	2.18
Total	100.00
Sulphur	0.80

The Steese mine, also known as the Summit Coal Company's mine, has been an important one, having a present daily output of 150 tons, but its area is nearly worked out. It is connected by a branch line with the Valley Railway. In all general characters it agrees with the

mine last described. The face of the coal runs N. 40° E. It finds market mainly in Cleveland, being used as household, steam and rolling-mill fuel. One-fourth is counted nut and slack. The coal mines large.

Mines of Norton Township.

The mines of this township are mainly of very different character from those already described, in that they are new mines, just coming to full efficiency. There are several large basins of coal already known, and there is no reason to doubt that other basins will be discovered as a result of future exploration.

The *Dennison Coal Company* (formerly, the Norton Coal Company) is now working a mine that was opened in 1881. More than 70 acres have been proved. The mine is making an output of 175 tons per day. It is connected by a narrow gauge railroad with the N. Y., P. and O. R'y, at Dennison Station. A part of the coal mines rather small, but that on the south side of the territory now worked is stronger and harder.

The normal cover of the coal is, first, black "chip slate," 6 to 12 inches; second, gray shale or soapstone, of variable thickness, and third, sandstone. This element ranges in thickness from 10 feet upwards. It frequently descends to the coal or even into the coal. Rock roofing is occasionally wanting altogether, only drift beds covering the seam. In such spots, quicksand is liable to be struck, which soon fills entries, and makes great trouble and expense. The shale above the coal is often soft and hard to keep up. The mine has thus poor roof throughout a good deal of the workings.

Under the drift cover, the coal is sometimes found partly bleached and disintegrated, and too weak even to sustain the roof, let alone any other considerations of value.

The average thickness of coal in the rooms now opened exceeds 4 feet. On account of the weakness above referred to, the width of the rooms is less than in many mines, not exceeding 7 or 8 yards. The depth of the rooms is 60 to 70 yards. The pillars are "gripped" to ensure as much strength as possible. Most of the coal is mined by powder.

The average composition is shown in the following analysis:

Coal of Dennison Mine—Lord—(Sampled by F. Keffer).

Moisture	5.03
Volatile combustible matter	40.21
Fixed carbon	48.35
Ash	6.41
Total	100.00
Sulphur	3.07

From these figures, it appears that the coal of this mine falls below the highest standard of the seam. The sulphur of the analysis is exceptionally heavy, and it is possible that there may have been some excess in the samples in this respect. The output of the mine is almost exclusively used as locomotive fuel.

The *Burnet Mine*, operated by the Brewster Coal Company of Akron, has a lease on several hundred acres, 50 to 75 of which have been proved to be productive. There are probably 200 acres of coal in this basin. Coal was first shipped from this mine in 1882. It is now sending out 250 to 300 tons per day. Of the sections from the surface to the coal, of which 30 or more have been drilled, a fair average would show the order herewith given:

Drift	25—30 feet.	Average depth of coal, 60 to 70 feet.
Bluish Shale	10—15 "	
Gray Shale	25—30 "	
Black chip slate	2—3 "	
Coal	4—5 "	

Fire-clay or "gannister".

Sandstone.

The rider seam, coal No. 2, is cut in many drill-holes. It is 12 inches thick, and 45 to 50 feet above the main seam. There is usually no rock above the rider.

The roof is fairly regular and strong. The face of the coal runs N. 30° E. The seat of the coal is generally clay, but in places it is a very hard rock, like gannister, striking fire with the pick. The thickness of the coal probably averages 4½ feet. Its limits, as worked, are 6 and 3½ feet. Powder is used in large quantity, viz., at the rate of 1 keg to 20 or 30 tons of coal. No undermining is done, and but little cutting, the whole work being done by the powder. One-fifth of the coal is estimated to go into slack, and one-tenth into nut coal, making 30 per cent. for the two. There is a good deal of "white cap" in the seam. This is popularly connected with a disposition to "run on the grate," but it is not really responsible for this bad characteristic.

The mine is connected by a branch with the N. Y., P. & O. R'y, and also with the Tuscarawas Valley R'y, and most of the output finds its way to the lakes, where it is used as a steam coal. Its composition, which is shown below, is seen to be somewhat exceptional for the seam. It agrees, however, with the analysis of the Dennison coal, already given. The figures are as follows (Sampled by F. Keffer):

Coal of Burnet Mine (Lord).

Moisture	5.62
Volatile combustible matter	38.28
Fixed carbon	49.74
Ash	6.36
Total	100.00
Sulphur	1.04

The *Excelsior Coal Company*, frequently known as the Wagoner Coal Company, of Akron, has both a slope and a shaft mine, which are located, respectively, in section 1, Wadsworth township, and on lot 81, Norton township. This mine finds its outlet, as do also the two previously described mines, by the 8 miles of branch railroad that connects the New York, Pennsylvania and Ohio Railway with the Cleveland, Lorain and Wheeling Railway. The mine was opened in 1881, and has been pushed vigorously since that time. Its daily output is 600 to 700 tons, and on August 24, 1882, 1,201 tons were taken out in 9 hours' time, and loaded into 79 flat-cars, which is believed to be the largest output ever made in one day by any mine in Northern Ohio. The only extra force employed was 4 drivers and 4 dumpers. Such a fact attests the good condition of the mine and the general efficiency of its management. It is under the charge of Frederick Ries, Superintendent.

The coal reaches an extreme thickness of 7 feet in the swamps, but this figure applies to but very small areas. It averages about 4½ feet. It is worked down to 3 feet. In an entry, all but 6 inches of the seam was lost at one point. Fully one-third is left in the mine in the territory that is worked.

The usual cover of the coal is shale, which reaches a maximum of 15 feet, over which a stratum of sandstone is generally found. The sandstone descends frequently, as elsewhere, at the expense of the shale,

and even of the coal. The rider seam, Newberry's No. 2, is often found 30 to 50 feet above the main seam. It seldom exceeds 18 inches.

A hill was struck in the main entry, in which the coal rose 15 feet above the usual level, and fell as much on the other side. The entry was cut down, showing, under the fire-clay, 14 feet of bluish-black shales. The fire-clay is plastic at one or two places in the property, but it is generally sandy and hard.

The composition of the coal, as sampled by Professor A. A. Wright, is as follows:

Coal of Excelsior Slope (Lord).

Moisture	6.10
Volatile combustible matter	37.01
Fixed carbon	51.00
Ash	5.89
Total	100.00
Sulphur	1.69

These figures show the coal a little nearer the usual type of the seam than the last two that were given, but it is still seen to be higher in water and ash than the best representatives of this field.

The coal is largely used by the N. Y., P. & O. R'y as a steam coal. It supplies in part the Akron rolling-mill, and much of it finds market in Cleveland as a domestic coal, and also as a lake coal. It is hard and strong, mining large, and carrying considerable "white cap" in its seams. There is apt to be a little bone coal at the bottom and also at the top of the seam.

Royalty averages about 20 cents per ton. It has mainly been paid on the weights of the small scales hitherto, but the growing practice is to pay only on clean coal.

The *Diamond Coal Works,* formerly known as the Humphrey's coal mine, is in Wadsworth township, near the main track of the N. Y., P. & O. R'y, and about 1 mile west of the township line. This basin originally contained about 150 acres of coal, of which 100 have already been mined out. The mine was opened in 1869. It is reached by a slope of 225 feet in length, the coal being about 75 feet below the surface.

The coal has the usual strength and quality, except upon the western boundary, where it is soft and rotten. It is mined by powder, with but little use of the pick. It has an average thickness of 4 feet, or a trifle

less, the swamps yielding $5\frac{1}{2}$ feet. The face of the coal runs N. 20° East. The roof of the seam is slate and sandstone, as in the mines already described. The slate is sometimes weak and troublesome. Sandstone often replaces it to the advantage of the mining. The little rider seam is found in many bore holes at 30 to 40 feet above the main coal. The floor is either fire-clay or the flinty gannister already described. The latter is about 1 foot thick where it occurs. The dip is to the south and east, and is sometimes as much as 15 or 20 feet to the mile.

The coal crops out in the creek below the railroad, but is not mined except by the shaft.

The output is largely used to supply a local demand and for the supply of adjacent villages and towns along the line of the railroad. In the winter the mine produces 200 tons per day, but in summer the production is not more than half of this amount.

The slack is all filled out and sold. It makes about 20 per cent. of the total output. The nut coal is generally sold with the lump.

The composition of the coal, sampled by Professor A. A. Wright, is as follows:

Coal of the Diamond Coal Works (Lord).

Moisture	6.25
Volatile combustible matter	36.75
Fixed carbon	53.12
Ash	3.88
Total	100.00
Sulphur	1.44

These figures indicate a coal fully up to the normal character of the seam for this district.

Shaft No. 2 of the Silver Creek Mining Company is situated $1\frac{1}{4}$ miles north, and $1\frac{1}{4}$ miles east of Wadsworth, the tributary territory to it being embraced within sections 16, 10 and 11, Wadsworth township. It is a new mine, opened in September, 1882. Probably 100 acres of coal, from 3 to 5 feet in thickness, will be found included in this basin. It is a strong, hard coal, with close end joints, and is mined by powder with but little use of the pick.

A band of pyrites is of frequent occurrence in the roof, immediately over the coal. Above the sulphur band lies a firm silicious rock, called

firestone, 6 to 12 inches thick, which is covered with shale or soapstone, 15 to 25 feet thick. Sandstone has not been found over the coal thus far. The floor is fire-clay, which is thicker than in many of the mines of the district, ranging from 2 to 5 feet. Thus far the mine has yielded 1 car of slack to 5 of lump, and 1 car of nut coal to 7 of lump. All the grades are taken out and sold.

The coal reaches the market by a branch track from the N. Y., P. & O. R'y.

An analysis of the coal is given herewith, as sampled by Professor A. A. Wright:

Coal of Shaft No. 2, Silver Creek Co. (Lord.)

Moisture	5.38
Volatile combustible matter	38.22
Fixed carbon	49.77
Ash	6.63
Total	100.00
Sulphur	1.91

These results associate the coal with some of the Norton township mines previously reported. The output is calculated to be 200 to 300 tons per day.

This company has other undeveloped coal property in the township, on the Hinddale and J. Overholtz farms, in sections 7 and 14.

Many of these facts are derived from Mr. E. G. Loomis, of Wadsworth, the Superintendent of the company, who is probably better acquainted with the coal of this immediate territory than any other person.

In these two townships, Norton and Wadsworth, there are several mines in addition to those already named, that have been the sources of large production, but which are now practically exhausted, and there are also several smaller or country banks.

To the first class belong such mines as the Burgess and the Bartger mine, and to the second, the Stuver and the Bees and Morgan banks, all of which are in Norton township. Most of these are old mines, for this region, having been worked 30 to 40 years. A body of coal, not yet shafted to, is reported near Hametown, Norton township, on the lands of Bodin, Steinbring, and Jones. Another body is reported on the J. Ballard farm, of Sharon township, north of Wadsworth. It is

claimed that 40 or 50 acres of 4 feet coal have been proved here by the Warner drillings.

The Wadsworth Coal Company mined coal on quite a large scale from 1869 to 1874. Their territory was adjacent to that of the Excelsior Slope, already described. The coal was exhausted from the Wadsworth Company's boundaries.

Chippewa township, Wayne county, lies directly south of Wadsworth, and Baughman township, of the same county, lies next south of Chippewa. These two townships are the only ones of Wayne county that are known to contain the Sharon coal. In them the seam is an important one, being now worked in a number of large shipping mines. A large acreage has already been worked out in Chippewa township, and no basins of large size remain unattacked, but mining has been begun in Baughman township within the last two years.

The chief mines of Chippewa township are the following:

The Chippewa mine (old), in section 36, exhausted.

The New Chippewa mine, in section 35.

The Silver Creek Mining Co., in sections 13 and 14, exhausted.

The Lantz mine (operated by Silver Creek Co.), in section 2.

The Woods mine (formerly owned by Silver Creek Co.), in section 15.

The Silver Creek Mining & Railway Company have built a branch railroad, connecting the Tuscarawas Valley R. R. (now the Cleveland, Lorain and Wheeling Railway) with a branch of the New York, Pennsylvaina and Ohio R'y, which leaves the main track a mile east of Wadsworth. The length of the combined line is about 8 miles. By means of it, the Diamond, Excelsior, Burnet (Brewster), Lantz and Woods mines all find outlet to either of the main lines.

The line of the road passes near the corner of the three counties, Summit, Medina and Wayne, and a little south and east of Doylestown.

A brief description of the leading mines of the township will here find place.

The *Lantz Shaft* was sunk in 1875–6. It is now operated by the Silver Creek Coal Company, of which Mr. E. G. Loomis, of Wadsworth, is Superintendent. It has probably 75 acres of coal connected with it. More than 30 acres have been already worked out. The maximum thickness of the coal is 6½ feet, and it averages 4 to 4½ feet. A considerable proportion yields 5 feet of coal. The quality of the

coal is good. It mines large and bears handling well. It is mined by blasting from the solid.

The roof is for the most part slate, and a streak of bone often covers the coal. A thin stratum of sandstone sometimes lies near the coal, and at the outcrop it is very flinty and hard.

The floor of the coal is a black slate, 5 to 8 inches thick, under which the gannister-like bed, already reported, is found. The bottom is very uneven. At one point, there is 21 feet fall in 25 yards.

There is more visible sulphur in the lowermost foot of the seam than elsewhere.

The market of the coal is mainly on Lake Erie, which it reaches by the Cleveland, Lorain and Wheeling road, the output being about 250 tons per day. It is valued as a domestic fuel as well as for steam production.

At a shaft in the southwest part of the basin, the rider seam, No. 2 of Newberry, is found, 2½ feet thick, and 63 feet above the main coal. It is 12 feet below the surface and has no rock cover.

This mine was filled with colored miners from Virginia at the time of a strike over the introduction of screens, 3 or 4 years since, and they are still retained.

The *Woods Mine* is located on section 15. It was formerly owned by the Silver Creek Company, but is now in the possession of Baysinger & Huffman, of Doylestown. It is an old mine for this district, having been open for 40 or more years. As many as 50 acres have been already mined out. It is entered by a drift entry, the coal lying 50 to 60 feet above the railroad.

The coal is of good quality, mining large and bearing transportation well, as a rule, but the lower part of the seam is sometimes a little short-grained and curly. It ranges in thickness from 3½ to 9 feet, and the average will exceed rather than fall below 4½ feet; of the maximum thickness, 9 feet, not more than ¼ acre is claimed. There is very little that is 7 feet thick. The mine is now taking thinner coal than in its earlier days. A little "bone" is sometimes found at the top of the seam. This phase is said to be connected with a sandstone roof. Generally, a black slate, 2 to 15 feet in thickness, is the immediate cover of the coal, over which is the usual sandstone stratum, which in one drill hole was 30 feet thick, but in some places, a shale comes down to the coal.

The floor consists of a dark-colored fire-clay, of low quality, about 4 feet in thickness.

The coal is mined mainly by powder, and at the present time, as is stated, only 1 car in 12 is slack, but formerly 1 in 8 was slack.

The coal finds market largely at Lorain, by the C. L. and W. R'y. It is used for steam coal on the lakes and also as a domestic fuel. Its production ranges from 60 to 80 tons per day.

The *New Chippewa Mine* lies west of the old mine of the same name. It is working towards the old mine, and it may owe its freedom from water to the drainage effected by the excavations to the east of it which overlook the Tuscarawas Valley. The new mine is located on the Cleveland, Akron and Columbus Railway, by which its coal finds market. About 500 acr s are tributary to it, and 30,000 tons of coal have already been mined from it, but there is only a small acreage of coal remaining. The average thickness of the coal is above 4½ feet, and will run close to 5 feet. It has the usual strength and hardness of the seam, especially where it has the protection of a shale roof. This is sometimes replaced by sandstone, at the expense of the coal. The shale referred to above is dark-colored, quite sandy, and breaks large. A few inches of bone frequently cap the coal. When this occurs, we find 1 foot or more of black slate succeeding, and then from 5 to 40 feet of shale or soapstone. A white sandstone is next above, and higher still the rider seam is found, about 65 feet above the main coal.

The floor is not a true fire-clay, but is a hard shale, close under which the pebbles of the conglomerate frequently are found.

The mine is entered by a drift, the coal lying 40 to 50 feet above the railroad, and the hill 100 feet higher. The coal is mainly sold for domestic use in Cleveland, though a good deal is distributed along the line of the railroad. The mine is producing 150 to 200 tons per day.

The coal has the usual strength. Much of it carries white cap, and some pyrite is visible, mainly as leaf sulphur.

Its composition as sampled by Prof. A. A. Wright is shown in the following analysis :

Coal of New Chippewa Mine (Lord).

Moisture	5.43
Volatile comb. matter	38.42
Fixed carbon	51.20
Ash	4.95
Total	100.00
Sulphur	1.79

The coal of the old mine was widely known and valued. It was styled the Blue Chippewa Coal, the designation coming from the appearance of the coal at the outcrop of the seam.

The facts as to this property were kindly furnished by Mr. Phillip Sonnhalter, one of the proprietors, who is thoroughly acquainted with this whole field.

The *Fox Lake Mine* of Baughman township is located in section 12. It is about 2 miles directly south of the old Chippewa mine. It is reached by a branch of the Cleveland, Akron and Columbus Railway, about 2¾ miles in length.

There are 500 acres under lease by the company, and it is counted that 100 acres, more or less, hold the coal. There has been already mined 50,000 tons, though the mine was opened but two years ago (May, 1881.) The output is 250 tons per day, and the capacity 500 tons. Three-fourths of the coal finds market in Cleveland and on the lakes. It has the average thickness of the seam, 4½ to 5 feet. The coal is steady in quality, is strong and hard, and comes out well from handling. The royalty is 10 cents per ton on all the coal sent out.

The roof, as shown in the slope, is slate or shale, covered with 15 feet of sandstone. The rider seam of coal was found in many of the drill holes, generally holding a thickness of 13 inches.

The floor is slate or hard shale for 6 inches, under which 4 feet of fire-clay are found. The clay rests on a conglomerate sandstone.

The upper part of the seam is somewhat long-grained and makes a little more ash than the balance. The lower 3 feet of the seam is as fine a coal as is yielded by any portion of the field, and the whole seam shows unusual excellence. The analysis of the lower part, taken by itself, is given herewith, as sampled by Prof. A. A. Wright:

Coal of Fox Lake Mine, lower 3 feet (Lord).

Moisture	5.87
Volatile combustible matter	36.96
Fixed carbon	55.50
Ash	1.67
Total	100.00
Sulphur	0.86

By taking the whole seam, a little larger quantity of ash is found, but the sulphur still runs very low, as shown by the figures given below:

Coal of Fox Lake Mine, whole seam (Lord).

(Sampled by Prof. A. A. Wright.)

Moisture	5.92
Volatile combustible matter	37.72
Fixed carbon	53.74
Ash	2.62
Total	100.00
Sulphur	0.68

No better coal is yielded by any mine of the Tuscarawas Valley than these figures indicate the Fox Lake Coal to be.

The mine yields at present 1 car of slack to 7 of lump, and one car of nut coal to 9 of lump coal. There is a little undermining done, but powder is expected to do most of the work in bringing down the coal.

The best rate in the use of powder is 1 keg to 35 tons. Much more is often used. The cost for powder to the miner is thus 10 cents at the lowest, per ton. Good miners put out 3 tons of clean coal per day. The elevation of the coal is 457 feet above Lake Erie by one railroad survey, and 454 feet by another. This puts it at approximately the same level as the Chippewa and Lester mines, which are near it. The Lower Mercer limestone crops out in the high ground above the coal.

Many of the facts in regard to this mine were kindly furnished by Mr. J. B. Zerbe, of Cleveland, Secretary of the Ohio and Pennsylvania Coal Company, of which the Fox Lake mine constitutes one of the properties. The latest reports from it, indicate that a limit will soon be reached to the southward, the floor being very uneven and the coal being often cut down to 1 foot, or even to less.

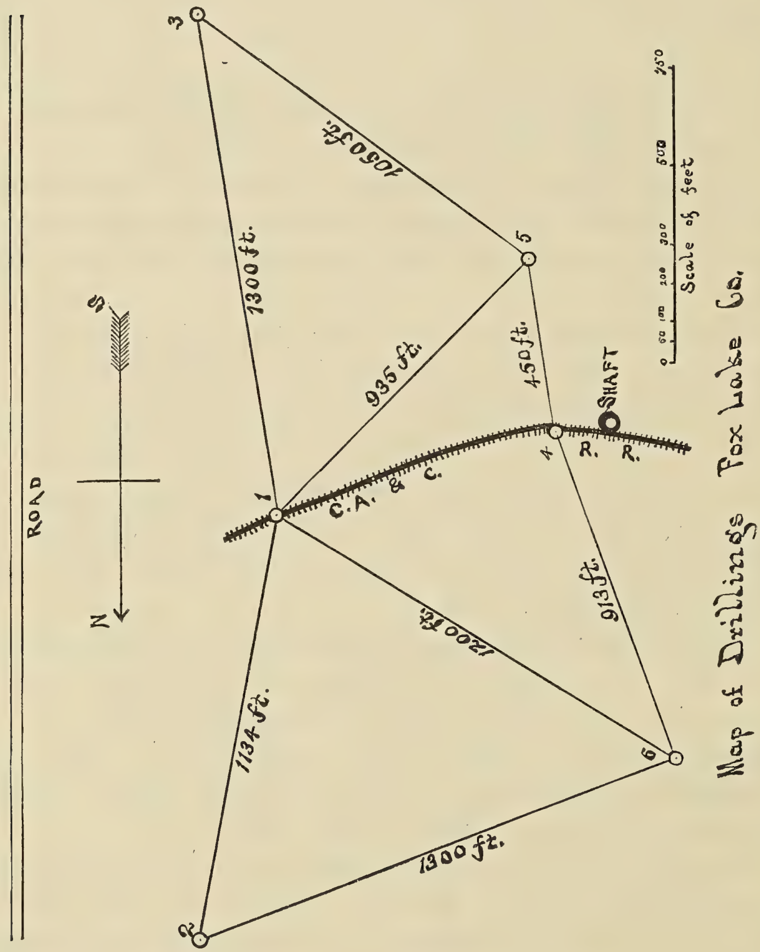
The explorations by which the coal was proved and developed are the last successful ones in this field. Access has been given to the records for the use of the Survey, and a brief statement in regard to them will be made, as illustrating the methods employed and also as a

guide to future work in this general field. The following diagram indicates the location of most of the test borings:

The surface elevations are referred to a base line, 47 feet below grade of Cleveland, Akron and Columbus Railroad, at junction 2 miles west of Warwick.

Track at shaft, 67 feet above base line. Coal at shaft, 455 feet (approximately) above Lake Erie, or at about the same elevation as coal in Chippewa mine.

FIGURE LXXII



No. 1.—650 feet east of shaft.

Earth	2 feet.
Black Shale	16 "
Slate.	
Coal (Quakertown, or No. 2)	2 "
Fire-clay	7 "
"Black band" (dark shale)	46 "
Hard sandrock	13 "
Soft rock and slate	2 "
Coal (Sharon, or No. 1)	3½ to 4½.

No. 2.—Record incomplete.

Quakertown coal	2 feet 2 inches.
Sharon coal	0 " 4 "

Latter, at a depth of 117 feet, 8 inches.

No. 3.—Surface elevation, 87.16 feet.

Surface	2
White Shale or slate	6
Black slate	1
Grindstone rock	9
Black slate	1
Coal (Quakertown)	0.8
Fire-clay	5
"Black band"	42
Hard, white sand rock	13
Slate	1
Coal (Sharon, or No. 1)	4.8

No. 4.—Fifty feet east of shaft, and under railroad track.
Elevation of surface, 66.54 feet.
Record incomplete.
Sharon coal, 5½ feet, at depth of 56 feet.

No. 5.—Six hundred and fifty feet south of shaft.
Elevation of surface, 70.61 feet.

Earth	4
Coal	0.8
Fire-clay	4
Gray slate	4
Gray stone	4
"Black band"	30
Hard sandrock	13
Coal cover	7
Coal (Sharon)	7.4

NOTE.—A room cutting through this seam showed coal, 8 inches; smut, 14 inches; coal, 5½ feet.

No. 6.—Surface elevation, 86.27.
Sharon coal struck at 76½ feet, 5 feet thick.

No. 7.—At office.

Surface elevation, 97.1 feet.

Yellow clay	20	feet.
White clay	4	"
Blue, soft soapstone	6	"
Dark-gray sandrock	4	"
Black slate mixed with coal	4	"
Gray sandrock	6	"
Fire-clay	5	"
"Black band"	25	"
Hard sandrock	6	"
Coal cover	12	"
Coal	5	"

No. 8.—To coal and stone mixed, 93 feet.

No. 9.—Two hundred feet west of shaft.

Surface elevation, 72.03 feet.

Surface	15
"Black band"	10
Dark sandrock	6
Hard white sandrock	14
Coal cover	12
Soft slate	1
Clean coal	5.6

We have thus far followed the outer margin of the Massillon coal field. Returning to the interior townships, we find this coal mined in Franklin township, Summit county, and also in Lawrence, Jackson, Tuscarawas, Perry, and Sugar Creek townships, of Stark county. Some of these townships constitute the western margin of the field.

A brief account of the mining industry of these several townships will here be given.

Mines of Franklin Township.

The most important mine of this township is the Nimisila mine, now operated by the Nimisila Coal Company of Cleveland and Massillon, Robert Rhodes, President. There are about 300 acres of land under lease to the company. The present company began work in 1877, and when the mine is in full operation, 125 men are employed, producing 175 to 200 tons per day. The mine has been worked for many years, and the largest estimate of the present owners does not exceed 40,000 tons for the available coal remaining. Operations are suspended at the present time, and when resumed the coal will probably be worked out.

The coal is fully up to the best standard of the seam in quality and strength. It is quite uniform in thickness, ranging from 3½ to 4 feet. There is no excess of sulphur.

The roof is sandstone oftener than shale. The face of the coal runs N. E. and S. W.

The mine is entered by a slope, and has but a single entry. It is drained by a 6-inch pump, but is flooded whenever the working is suspended. It is connected by a branch railroad with the Cleveland, Akron, and Columbus R'y, and also with the canal. It is located in section 15. Other openings have been made to the coal in the same section.

The Franklin Slope is a nearly exhausted mine in the same vicinity.

In the southeastern part of the township, near Manchester, in sections 26 and 27, coal of good promise has been found by boring. There are about 200 acres in the basin, as is supposed. Brewster & Sons' Coal Company holds a lease upon it.

Coal was once mined on section 34, and it is also known to underlie section 33 in mineable thickness.

The Johnson mine, in section 1, connected with the mines of Coventry township, comes under the general description already given of that field.

Lawrence Township, Stark County.

This township is undoubtedly the most important of the entire field, or at least has been so. Fourteen more or less important mines have been opened within its boundaries, and while several of them have been exhausted, there is still a large production of excellent coal. It is this township, in fact, more than any other, that has given character to the entire field.

Following the Tuscarawas Valley from the northward, we find, on entering the township, a number of partially or completely exhausted mines in the bordering hills.

The *Lester Mine* (situated in the north part of fractional section 6) belongs to the same basin with the Chippewa mine, or, at least, to one closely connected with it. It was worked as a railroad mine for some years, but at present it is only a country bank. The Crawford Coal Company had possession of it in the time of its largest development. The coal was found to be soft, and was mainly used as a steam coal on

the Tuscarawas Valley Railroad (C. L. & W. R'y), but at present it is used with acceptance as a household fuel by the farmers of the neighborhood. The coal is mainly under light cover. It holds an average thickness of 4 feet. It lies about 100 feet above the Tuscarawas Valley, and 448 feet above Lake Erie. There is considerable territory adjoining it that is high enough to hold the coal, but no thorough explorations have been reported.

The Deep Boring on the Wagner Farm, near Canal Fulton.

It is within a half mile from the Lester mine that the deep drilling has recently been made, at the bottom of which it was claimed that 6 feet of coal were found, at a depth of about 400 feet below the level of the Valley. The drilling was made by Messrs. McFadden and Campbell, of Canal Fulton, and the find was reported about the middle of October. As many of the letters and dispatches were dated at Akron, the claim has been connected with this town, and the "deep coal of Akron" has acquired a wide-spread notoriety.

It appears that traditions of a coal-seam, far below the Valley level, have been current in the neighborhood for the last 50 years. They all go back to the drilling of the deep hole for salt water by a former resident of the Valley, now long since deceased, named Kroft. The date of the drilling was 1823–4, as nearly as it can be fixed. There is no one now left in the Valley that claims to have seen the coal, and but few that claim to have heard of it at an early day. A letter recently received from Mr. Peter Kroft, of Winnemac, Ind., son of the man who drilled the hole, is explicit in its denial of any coal being found in the boring. Mr. Kroft declares that he remembers all the history of the boring. He says that the rock was reached 8 feet below the surface, and that it held uninterruptedly for 400 feet, and that no coal was found at any point.

The samples brought up by the present drillers from the hole, being bright and lustrous and not soiling water, were pronounced *anthracite* by parties near at hand, and probably in accordance with this view, a chemist of the neighborhood found more than 80 per cent. of fixed carbon in them. A true analysis, made by the Chemist of the Survey, showed less than 50 per cent. of fixed carbon, and made the composition agree closely with the so-called *albertite* of the Ohio black shale, to the level at which this product is often found the boring had pene-

trated. The small fragments, first analyzed by the survey, also agreed fairly well in physical characters with albertite, and gave color to the view that had been already suggested, that one of the thin sheets of this substance that the black shale contains had been accidentally met in the drill-hole. Other and larger samples, afterwards received, disproved this view, however, and established the character of the mineral brought out of the hole as true coal, containing mineral charcoal and distinct traces of vegetable structure. The coal was of the type of the Pike Run or Coshocton coal, the Middle Kittanning seam of our series, and No. 6 of Newberry. This seam in eastern Ohio approximates to pitch coal in composition, containing less than 50 per cent. of fixed carbon, and more than 40 per cent. of volatile matter. The albertite of the black shale gives quite similar results. The analyses referred to above are the following:

No. 1. "Albertite," from Black Shale, Avon Point, Lorain Co., O.
" 2. " " " " "
" 3. Coal from drill-hole, samples rec'd from I. M. Taggart, Canal Fulton.
" 4. " " " R. S. Paul, Akron.
" 5. " " " John Campbell, Canal Fulton.
" 6. " Blue Rock mines, Muskingum Valley.
" 7. " Pike Run mines, Tuscarawas county.

All of them were made by Professor Lord for the Survey.

	1.	2.	3.	4.	5.	6.	7.
Specific gravity....................	1.251	....	1.231	1.276	1.282	....	....
Moisture	3.3	4.42	2.3	3.66	2.56	3.50	2.69
Volatile combustible matter	43.5	41.08	48.0	45.54	43.83	46.44	44.74
Fixed carbon or coke..........	50.6	52.65	48.70	47.70	49.50	45.87	46.95
Ash	2.6	1.85	1.10	3.00	4.11	4.9	5.62
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur................................	....	1.19	....	....	0.70	3.84	3.09

From an examination of these figures it will be seen that No. 3, the coal from the drill-hole, furnished by I. M. Taggart, Esq., Canal Fulton, keeps well within the figures of the Avon mineral in every particular. Its ash runs very low, and its specific gravity is also low. The remaining analyses of the coal brought out of the hole, viz., Nos. 4 and 5, show an increase in the ash, which is the most dis-

tinctive element, and thus bring the samples up to the level of the ordinary coals of several of our well-known fields.

The depth of the so-called "find" below the Sharon coal that overhangs it, in the Lester and other mines, ranges from 475 to 500 feet. The claim made by some that the "find" is in reality the Sharon or No. 1 coal, carried deeper than has been supposed by an unusual dip, is not supported by a single fact, and is negatived by all the facts, and does not therefore deserve refutation. The level at which the "find" is located is below the place of the Berea Grit. The testimony of the drillers is to the effect that they found "rock" all the way down, and that nothing corresponding to the Cuyahoga shales was encountered. The record was not kept with care, however, and there is nothing decisive in the testimony as to the series penetrated.

The best practical judges of the facts in the case unite in the view that the coal taken out of the hole was first put there, "with intent to deceive". The suggestion that the drillers struck one of the sheets of Avon "albertite", with which the shales are occasionally intersected, is set aside by the vegetable structure found in the later samples of the coal from the drill hole.

Since writing the above paragraphs, further exploration has been made and much clearer light has been thrown upon the claim. Two wells have been drilled by residents of Clinton, the last one within ½ mile of the original Wagner well. Through the courtesy of Andrew Donnenwirth, J. P., who was one of the company engaged in the exploration, the records of these two drillings are herewith furnished:

The first drill-hole showed—

Earth	3 feet.
Sandstone	13 "
Pebble rock and sandstone	80 "
Cuyahoga shale	200 "
Berea grit	54 "
Bedford shale, etc	100 "
Total depth	450 feet.

The second record showed 80 feet of sand and clay. The Cuyahoga shale was thicker and the Berea grit not quite as thick. The drill stopped in Bedford shale at a depth of 443 feet.

In other words, both sections are normal in all respects, and the

excitement that claimed to revolutionize the Geology of North-eastern Ohio, is shown to be without a shadow of support from the facts.

The Buckeye, Fulton and Barney McGue mines are all located on the west side of the Tuscawaras river, and from 50 to 75 feet above it. They are opposite to the village of Canal Fulton. They belong essentially to one basin, though complete continuity cannot be claimed for the several deposits. The Fox Lake workings are between 2 and 3 miles due west of these, and connections between these areas are known to exist. The three mines named above are all substantially exhausted, and in fact have been so for many years. Pillars, crop coal, and occasionally small troughs of coal, that have been passed by in former workings, are all that keep up the production in this territory at present. The coal removed was mostly 4 feet in thickness and all the conditions agreed with those already described.

The Lawrence Mine (Maple Grove.)

Passing to Section 29, just north of and connected with the Pittsburgh, Fort Wayne and Chicago R'y, we find one of the large mines of the field. It is operated by the Ridgway Burton Company, of Massillon. It holds lease upon 350 or more acres of land, and is now producing 200 tons per day. The coal is 75 to 100 feet deep, more than half of the section being drift. Quicksand is often very troublesome.

The mine has been worked for a number of years, and all the coal that was first known has been taken out. The old workings were terminated abruptly on the north by a "horseback" or intrusive sandstone, but when coal was found of good thickness beyond this a level was pushed through the rock, and all the coal of the mine now comes from this new territory.

The coal is somewhat unsteady in thickness, being frequently traversed by the sandstones that mark the channels cut through the original swamp. It averages over 4 feet. The face of the coal runs N. 25° E. The roof is dark slate, overlain by gray shale. The floor is 2 to 4 inches of hard slate over fire-clay. It mines fairly large, but does not bear handling as well as the coal of some other mines. One keg of powder brings 20 to 25 tons, but some of the rooms require no powder. One-fifth of the coal filled out by the miner passes through

a screen of $1\frac{1}{4}$ inches between the bars. Of this amount, $\frac{3}{5}$ are nut and the balance slack. These figures are meant to express the average; the range is considerable. The miner expects to send out 3 to $3\frac{1}{2}$ tons per day; the present price of mining is 85 cents for one-half the year, and 95 cents for the other half. The coal is not often followed below 3 feet, and no allowance for a low seam is required.

The coal is highly approved for household fuel and for steam generation. The top of the seam is a little more splinty in character than the remainder. Analysis shows the coal to be of admirable quality, and that it attains as high a standard of excellence as the coal of any mine of the Massillon field. The following results, obtained by the chemist of the survey, show on what foundation these claims rest. The coal was sampled by Mr. Frederick Keffer:

Analysis of Coal of Lawrence Mine (Lord).

Moisture	5.90
Volatile combustible matter	35.25
Fixed carbon	57.23
Ash	1.62
Total	100.00
Sulphur	0.76

The Minglewood Mine.

The Minglewood mine holds a lease upon 600 or more acres of land in Sections 31 and 32. There are probably 100 acres of coal contained in this property, as indicated by the test drillings. The mine is newly opened, the first coal having been taken out in 1882. It is sending out, at present, about 200 tons per day, the entire product being taken by the Pittsburgh, Fort Wayne and Chicago R'y, which traverses the property.

The coal appears here at its best, bright, free from sulphur, and strong. The figures of the last analysis would doubtless apply to this mine as well. It exceeds, as far as worked, 4 feet in average thickness, ranging from 3′ 8″ to 5′. The face runs N. 20° E.

The nut coal and slack are washed at this mine, the only instance of this sort in the Valley. The work is done at small expense, the mine water being used for this purpose. All the dust is removed, and much of the slate also. The apparatus is ingenious, simple and effective. The process well deserves a wide application.

The Oak Hill Mine.

In Sections 34 and 35, is a mine now known as the Oak Hill mine, which has been in operation 12 years, and which is now near its limits. All the coal at present yielded by it comes from pillars and entry walls. Representative sections, by which the coal is here reached, are as follows:

Drift	23	feet.	
Sandrock, Massillon	22	"	
Dark slates	10	"	
Black slate	30	"	
"Coal rock"	12	"	
Slate	1	"	
Coal	3	"	

Drift	19	feet.	
Sandstone	16	"	
Dark slate	7	"	
Hard gray rock	4	"	
Dark slate	11	"	
Soapstone	3	"	
Black slate	14	"	
Brown rock	3	"	
Coal	4	"	

Drift	40	feet.	
Dark slate	18	"	
Hard sandrock	2	"	
Brown rock	11	"	
Hard white sandrock	3	"	
"Coal rock"	4	"	
Coal	1	"	9 in.

The roof is firm and reliable, and the coal lies so deep that no trouble results from quicksand. The coal is often followed in this mine down to 2 ft. 6 inches. Its maximum thickness is $4\frac{1}{2}$ feet and its average $3\frac{1}{2}$ feet. It is undoubtedly continuous with the coal of the Aberdare mine.

The Mountain Mine.

This mine, which is operated by the Rhodes Coal Company of Cleveland, has under lease about 360 acres of land, in N. E. $\frac{1}{4}$, Section

36, but the coal has been mainly worked out. It originally held about 60 acres. The mine was first opened in 1871, and has yielded a large amount of excellent coal. It is now producing 275 to 300 tons per day, mostly pillar and crop coal. The shaft is located at about the center of the basin, and is 140 feet deep.

The coal has been followed as low as 18 inches, but it reaches the usual average of 4 feet in all of the main workings. The mine has a good roof, better, in fact, than the average. The product of the mine is shipped by the Cleveland, Lorain and Wheeling R'y, with which it is connected by a side track.

A number of exhausted mines are found in this township, some of which have been largely productive and profitable. Among them are the Aberdare shaft, the Crawford slope, the Crawford shaft, the Staeffer mine, the Willow Bank mines, Nos. 1 and 2, and the Burton Furnace Company's mine.

To this list, most of the mines already described, will soon require to be added. But few have any large acreage before them.

All of the mines above named, and several of those that have been previously described, constituted, in reality, one almost continuous field, by far the largest and most valuable of the entire district. The Willow Bank Section of this field must have aggregated 200 acres, taking in the Willow Bank, Mountain, Burton Furnace and Clark mines.

Mines of Jackson Township.

There are three mines of the Massillon coal now open in this township, viz., the Willow Bank, No. 3, or "Ground Hog mine", Willow Bank, No. 5, and a new mine opened in Section 16. These will be briefly described. To them may be added an abandoned mine, formerly known as the Bridgeport mine.

The Ground Hog Mine.

This mine is situated in Sections 19, Jackson, and 24, Lawrence townships. There are under lease, to the Rhodes Coal Company, 280 acres, but less than 100 acres hold the coal. Like the mines already described, this one has been worked almost to its limits. Most of the coal now yielded comes from pillars, and at the furthest it will be kept

in operation but a few months. The coal averages 3 ft. 4 inches in thickness, but is seldom mined below 2 feet 9 inches.

The coal is disposed in a long and narrow basin, depressed in its central parts. The axis of the basin extends N. E. and S. W. On this account, it has been found necessary to drive the entries quartering, the main entry having a direction of east of N. E. The coal mines large and bears handling well. It is strongest on the edges of the basin. The proportion of large coal is greater here than in most other mines, a large part of the slack and nut coal being thrown back into the waste by the miners. Twelve cars are loaded with round coal to one of nut and slack, according to the figures reported. Such a result can be obtained only by a wanton waste of the product of the mine.

The roof is fair, but not as good as the best. It consists normally of slate or shale.

Where the coal is thin, it is capped with a few inches of bone, a black slate, sometimes passing into poor coal.

Whenever the edge of the swamp is reached, the sandstone comes down to the coal, cutting out the normal cover.

The following section, obtained from the drill-holes by which this property was proved, illustrates the general stratification:

	Feet.	Inches.
Sand and gravel	23	0
Clay and soapstone	3	0
Blue rock	2	0
Rock and coal (Quakertown seam?)	0	6
Slate	3	0
Gray sandrock	2	10
Soapstone	3	0
Hard, white sandstone	8	0
Gray sandstone	7	0
Slate	3	0
Soapstone	6	6
Slate	13	8
Hard, dark sulphurous rock	1	6
Hard, white sandstone	11	6
Light gray rock	22	3
Dark gray rock	9	0
Black Slate	0	9
Bone coal	0	9
Coal	4	6
Total	126	3

Willow Bank Mine, No. 5.

This mine is situated in Section 31, Jackson, and in Section 6, Perry township. It is a comparatively new mine, having begun its work in 1881. It is producing 250 to 275 tons per day, and has been in quite constant operation. Its coal goes out by the Cleveland, Lorain and Wheeling Railway, with which it is connected by a narrow gauge track.

The area of coal in this mine is estimated to have been originally 30 to 35 acres. Its thickness is about 3½ feet for an average.

The roof is normally slate. Where the coal runs out, quicksand from the drift formations overlying, sometimes comes in, to the great damage of the mine. A seam of sandstone, 2 inches in thickness, 4 inches above the bottom of the coal, extends over a considerable area in the mine, a fact that stands by itself in this field.

The composition of the coal is shown in the following analysis by Professor Lord. The coal was sampled by Mr. Frederick Keffer for the Survey:

Moisture	4.80
Volatile combustible matter	37.81
Fixed carbon	53.22
Ash	4.17
Total	100.00
Sulphur	0.73

Another body of coal of good promise has lately been opened by the Rhodes Coal Company, in Section 16, about ⅓ of a mile north of Willow Bank, No. 3. It is known as the Conrad mine. The area of this basin is thought to exceed 50 acres.

A single section in one of the trial borings will be given here:

	Feet.	Inches.
Gravel and drift	35	9
Slate	1	6
Gray sandrock	6	6
Slate	3	3
Coal	0	3
Soapstone	6	0
Slate	13	0
White sandrock	18	0
Light-gray rock	20	0
Dark-gray rock	7	0
Black slate	1	6
Bone coal	0	3
Coal	4	4
Slate	0	6

COAL MINES OF TUSCARAWAS TOWNSHIP.

Three mines are now in operation in this township, viz., the Sippo, the Windsor, and the Grove, No. 2. The Massillon City mine has only recently been abandoned. It was also known as the Brookfield mine. It has yielded a large amount of coal, of high quality.

THE SIPPO MINE.

The Sippo mine is located in Section 1, and was formerly known as the Fruit Hill mine. It has been in operation 8 years, 2 years as a country bank, and 6 years as a shipping mine. It has a large capacity, sending out 350 to 500 tons, when running full. It has side tracks to both the Wheeling and Lake Erie, and the Cleveland, Lorain and Wheeling Railways. The section in the shaft is given as follows:

Drift	10	feet.
Sandrock	18	"
Compact "light rock"	70	"
Fire-clay	3	"
Hard dark rock	6	"
Pepper and salt sandrock	5	"
Hard, dark rock	27	"
Slate	2	"
Coal	4	"

The coal has a good roof and runs steady. It has a slate floor above the fire-clay. Under the clay is a very hard sandrock. The quality, as elsewhere, is a little poorer at the top of the seam, the coal there inclining to a long-grained or splinty character. The "white cap," so characteristic of Massillon coal, is found fully developed in this mine. The face of the coal bears N. 26° E. The coal averages about 4 feet, ranging between 2½ and 4½ feet. The mine is provided with a slope, as well as with a shaft, the former being 500 yards long.

An exceptional fact in the dip is to be noted in this mine. The seam inclines to the northward, the level of the coal falling 14 feet in ¾ of a mile. This unusual and unexpected fact complicates the drainage of the mine to some extent.

The coal is disposed in a narrow and somewhat tortuous basin, varying from 60 to 100 yards in width, and extending through 1¼ miles. Its general direction is N. E. and S. W. The entries cannot be driven on the face of the coal, because, in this way, they would soon come to

trouble, but they follow the sinuosities of the swamp, as they best can.

The composition of the coal is shown below, the sampling being done by Mr. Frederick Keffer for the Survey :

Analysis of Sippo Coal (Lord).

Moisture	5.09
Volatile combustible matter	37.28
Fixed carbon	53.30
Ash	4.33
Total	100.00
Sulphur	1.03

The Windsor Mine.

This mine is also situated in Section 1, Tuscarawas township, in the S. W. ¼. It is a small mine, connecting by a narrow gauge track with Massillon. It holds a part of the basin, just described, and, in fact, it is worked through into the Sippo mine, getting its ventilation by means of the furnace, and its drainage by means of the pumps of the latter mine. It produces 40 to 50 tons per day, but has only a small territory on which to work.

The Grove Mine, No. 2.

This mine is located in Section 24, Tuscarawas township, which adjoins Section 19, Perry township, in which the abandoned mine, Grove No. 1, is located. The two mines are separated by a broad "horseback" of sandstone.

There are over 600 acres under lease by this corporation, but the coal is already almost exhausted. Only pillar coal is now produced by No. 2, and this at less than 200 tons per day.

The mine is entered by a shaft 140 feet deep. It strikes the summit of the basin, from which fact the drainage is complicated. Branch pipes must be carried forward to all the workings from the pumps at base of shaft.

The coal is not worked below 2′ 9″, as a rule. Its greatest thickness is 5 feet. Where horsebacks occur, they generally cut out the coal altogether, instead of merely reducing its thickness. The roof is excellent, consisting of 6 to 20 inches of black slate, covered by a gray sandrock. Bone coal occurs at the top of the seam, and makes some trouble for miner and operator. Nodules of ore are frequently

found at the top of the slate. The floor is a hard slate, but in the "hills" of the mine, the conglomerate comes up to the coal.

The coal has the full strength and quality of the seam. It is brought out to the Cleveland, Lorain and Wheeling R'y, the mine cars being lowered into the valley by a double track incline, operated by gravity.

Pigeon Run Mine.

This mine is located in Sections 26, 35 and 36, Tuscarawas township. It holds leases on about 660 acres of land, but the main coal basin, which includes 50 to 60 acres, is already exhausted, and pillars are now being drawn in the mines. The shaft gives the following section:

Drift, sand, clay, etc	85	feet.
Soapstone and slate	60	"
White sandrock (Massillon)	15	"
Gray rock	20	"
Black slate	4	"
Coal	5	"
Total	185	feet.

The mine delivers its coal to the Cleveland, Lorain and Wheeling Railway.

The average thickness of the coal is not less than 4½ feet. Perhaps it runs as high as 5 feet, for there are large areas in which it holds fully 6 feet. In one pocket of the mine, near a horseback, the coal thickened up to 9 feet for a small area. Where the coal is thickest, it is apt to bear a 6-inch bone coal, which often gets into the cars. The face of the coal bears N. 25° E. to N. 30° E. The coal is worked "on the square", all entries being run on face and ends. It dips in the large way to the southwest, but there are many local flexures.

As a whole, the roof is good. It consists of about 4 feet of black slate, overlain by the gray rock reported elsewhere. Sometimes the slate disappears, letting the rock down upon the coal, always to the detriment of the latter. Nodules of ore are found in and immediately above the slate.

The quality of the coal is, in all respects, approved. It was used for a time in one of the Massillon furnaces, successfully.

On the N. W. ¼, Section 2, Tuscarawas, and S. W. ¼, Section 35, Lawrence township, three drill-holes have shown a body of mineable

coal of good promise, the lease of which is held by Hon. John G. Warwick. The record of one drill-hole is as follows:

Drift	56 feet.
Slate	27 "
Soapstone	6 "
White sandrock	2 "
Dark-gray shale	16 "
Light-gray shale	46 "
Slate	2 "
Coal	5 "

Another body of coal, but less promising, has been proved in Section 13, Tuscarawas township. The thickest part of the seam shown by the drills was 3′ 6″. The leases are held by Hon. John G. Warwick and the Rhodes Coal Company.

Mines of Perry Township.

The mining of the lower coal in this township is a thing of the past. The Grove mine, No. 1, has already been referred to. The once famous Warmington mine is in the same category, worked out and abandoned. Two mines are opened in a higher coal, probably the Tionesta coal, on the Koontz and the Hankins' farms, respectively, in Section 4. The coal is $2\frac{1}{2}$ feet thick, and of fair quality. Both mines are merely country banks, worked in winter for the supply of the neighborhood.

Mines of Sugar Creek Township.

Three mines in the Sharon or No. 1 coal are open in this township. They are known as the Camp Creek, Elm Run, and Justus mines.

Camp Creek Mine.

This mine is located in Section 2, Sugar Creek, and it also holds territory in Section 35, Tuscarawas. The basin is either continuous or closely connected with the Pigeon Run basin. It is operated by Oliver Young, Elyria, O. The coal is brought to market by the Cleveland, Lorain and Wheeling R'y. It has been in operation a little more than 6 years, and 40 to 50 acres have already been mined out. Its output ranges from 250 to 300 tons per day. Its leases control about 400 acres of adjacent territory.

The shaft is 166 feet deep, counted from the natural surface. The section is given below:

Drift.	Drift-clay, yellow	15	feet.
	Gravel and clay	1	"
	Blue clay	20	"
	Cemented sand	1	"
	Blue clay	4	"
	Gravel	5	"
	Quicksand	2	"
	Gravel	3	"
	Blue clay	2	"
	Fire-clay	5	"
	White shale	4	"
	Gray shale	2	"
	Hard rock	1	"
	Black band rock	12	"
	"Fire-stone," etc	15	"
	Hard black rock	6	"
	Gray "fire-stone"	5	"
	White shale	2	"
	Blue "fire-stone"	40	"
	Gray "fire-stone"	23	"
	Black slate	3	"
	Coal	4½	"

The coal of this mine has certain features that are not elsewhere found in the entire field. The shaft lies midway between two basins of coal, one lying to the north-west and the other to the south-east. The former has an approximate area of 400 by 175 yards, the longer axis extending nearly east and west. The second basin has an area of 300 by 150 yards, approximately, and its greatest length is also in an east and west line. The two basins have an area of about 125 acres. The two basins are connected by an entry, 135 yards long, cut partly through sandstone and partly through coal, the latter not exceeding 2 feet 4 inches in thickness.

The south-east basin is in all respects normal and regular, the coal holding an average thickness of 4 feet, mining large and bearing transportation well.

The north-west basin has the unusual features referred to above. It holds two distinct seams of coal, the lower one, which is 14 inches thick, having all the characteristics of the Massillon seam generally. The upper one, which averages 4 to 4½ feet in thickness, is denominated the "hard coal", the lower bench being termed the "soft coal". The hard coal approaches cannel in character, being strong and

heavy, having a smooth surface and a waxy luster, but showing a cubical and not a conchoidal fracture. In color, it is dead, lacking the blackness of the ordinary seam. Its ash is dark-red, of so pronounced a color, that it has been ground with oil, and used for a paint. Its composition is indicated in the following analysis, by Professor Lord, of samples taken by Mr. Frederick Keffer, for the survey:

Camp Creek "Hard Coal".

Moisture	3.11
Volatile combustible matter	42.04
Fixed carbon	40.15
Ash	14.70
Total	100.00
Sulphur	1.06

It is used only for a grate fuel, and the composition shown above does not fit it for large service or popularity in this field.

Whenever this double seam grows thinner as a whole, the lower or Massillon coal grows thicker. The coal connecting the two basins is entirely of the latter character.

The roof of the hard coal is 4 to 18 inches of bony and worthless coal in the swamp, but near the edges of the basin the gray rock comes down directly upon the coal. The roof of the east basin is 6 inches to 2 feet of black slate. In a few places, this slate disappears, letting the sandstone down upon the coal. No complaint of bone is made in the cover of this coal.

The floor of both basins is generally fire-clay, but in some cases, a flinty, gannister-like rock takes its place.

The area already mined is estimated to be between 40 and 50 acres mainly in the east basin. This body is therefore near its limits.

Elm Run Mine.

Elm Run mine is located in Sections 3, 4 and 5, and holds by lease about 700 acres of land. Its coal is essentially continuous with Grove mine, No. 2, and with Camp Creek mine, last described. It is thought that a large acreage of coal will be found here, coming up almost to the proportions of the Willow Bank basin. The coal is of approved quality in all respects. It has full thickness, as far as de-

veloped, and good strength. The roof is good, consisting of slate, thus far.

The section found in the shaft is given as follows:

	Feet.	Inches.
Drift clays and gravel	49	0
Sandrock	13	0
Broken rock	5	0
Soapstone	3	0
Gray sandrock	3	6
Broken rock	6	0
Soapstone	25	0
Coal (Quakertown seam or No. 2)	1	0
Black slate	25	6
Gray rock	22	0
Black slate	1	6
Coal (Sharon seam or No. 1)	5	0
Total	159	6

The section is interesting from the fact that the Quakertown coal appears here, after a long interval, in which no trace of it is shown.

The mine was opened in 1882. Its coal goes out by the Cleveland, Lorain and Wheeling R'y.

Justus Mine.

The Justus mine, No. 2, is located near Justus, in Sections 14 and 15. It was opened in 1882. It controls by lease 280 acres, and the coal is estimated at 75 acres. It connects with the Cleveland, Lorain and Wheeling Railway, by a branch track. The shaft is 130 feet deep. The section found in shaft is as follows:

Drift.	Clay and gravel	70 feet.
	Quicksand	20 "
	Slate and gray rock	25 "
	Coal	5 "

The quicksand proved troublesome and expensive in sinking the shaft. The seam is undulating, but not unsteady. The hills rise 35 feet above the swamps. Horsebacks do not occur in the body of the basin. The dip is to the south. The face is said to be N. 7° E, a deviation from the general direction of N. 20° to 30° E. The roof is dark, gray rock, no slate being thus far found. The coal rests on a fire-clay floor. The top of the seam is more splinty or longer

grained than the remainder, but no distinction is made in the output. It becomes bone in parts of the mine and is then rejected. The bone ranges from 4″ to 11″. Taken as a whole, the coal of this mine is said to have a larger proportion of the short-grained or curly coal than that of any other mine, and by this its adaptation to household use is ensured. The composition of the coal, as sampled for the survey, by Mr. Frederick Keffer, is shown in the following analysis by Professor Lord:

Coal of Elm Run Mine, No. 1.

Moisture	5.65
Volatile combustible matter	36.08
Fixed carbon	55.70
Ash	2.57
Total	100.00
Sulphur	0.91

The seam carries a standard height of 4′, but it swells up in the swamps to 7 and 8 feet at times.

Over a $1\frac{1}{8}$-inch screen, a bank car of 2,750 lbs. will lose 450 lbs., 200 of which are slack, and 250 nut, but sometimes 2,400 lbs. of clean coal will be sent out on a car.

One keg of powder is commonly required for 25 to 27 tons, making the cost to the miner from 10 to 15 cents per ton.

Mines of Bethlehem Township.

Three mines have recently been opened in Bethlehem township, the most southerly of the Massillon field. They are the Garfield and Rose Hill Shaft and the Beaver Run Slope. They are all in proximity to the village of Navarre, the first two being west of the Tuscarawas river, and the third being on the east side.

The Garfield mine is operated by Oliver Young, of Elyria. The shaft is 112 feet deep. The coal holds the full thickness of the seam, being about $4\frac{1}{2}$ feet thick. The basin is a narrow one, and not more than 40 acres are known to belong to it. The coal inclines to a long grain, and is better adapted to steam production than to household use. The present output of the mine is about 250 tons per day. The coal goes out by the Cleveland, Lorain and Wheeling Railway.

The Rose Hill mine, also on the west side of the river, is a mine of the same general character as the Garfield, but its coal is counted of somewhat better quality, coming up to the ordinary Massillon standard. The area of coal tributary to it is judged to be about 40 acres, with a full thickness of 4½ feet. It is operated by Hon. Anthony Howells, of Massillon.

The Beaver Run mine has a daily output of about 250 tons. It has three lines of communication, viz., the Wheeling and Lake Erie Railway, the Connotton Valley Railway, and the Tuscarawas Valley canal. The coal is about 4 feet in thickness, and of fair quality. The basin is estimated at 30 to 50 acres.

Conclusion.

This completes the brief review of the Massillon coal field which was undertaken. It is a matter of regret to find that this excellent coal is so limited in area, but though the first discovered bodies of it have already been mainly exhausted, there is as much proved coal before the miner now as there was 20 years ago, and there is no reason to doubt that further exploration will make important additions to what is now known. The production is certainly not likely to be increased, but in the opinion of the best judges, it will probably be maintained for a score of years, at approximately the present figures. The present annual production runs close upon 1,000,000 tons. The scene of activity in the field has already been shifted to the west and south since work was first begun, less than 25 years ago. This advance to the westward has already reached its limit, but the new basins to the southward have not yet been brought to their largest production. So far as can be seen, Lawrence, Tuscarawas, Sugar Creek and Bethlehem must supply the Massillon coal for the future, in the main.

A large and valuable basin has already been proved, but not opened, 2 miles south of Justus. It is partly on the Kemp farm, and is known as the Kemp basin. The length of the basin has been shown to be at least 1¼ miles, and it will make without doubt a very valuable addition to the field. The coal is leased by Hon. Anthony Howells, of Massillon.

This, however, constitutes the southern limit of the field, according to present knowledge. A considerable amount of exploration has been made and is now going forward to the southward, but so far without result.

CHAPTER XIII.

THE COAL SEAMS OF THE LOWER COAL MEASURES OF OHIO—Continued.

MINES OF HOLMES COUNTY.

By Albert A. Wright.

Holmes county occupies the interval between Tuscarawas county and the border of the coal field. The coal-seams of the latter county, from the lowest up to the Upper Freeport or No. 7, extend westward into Holmes, where they all disappear. The lower seams, as they extend north-westward, are successively brought above drainage, so that all the seams mentioned are exposed in the western half of the county; while upon the south-eastern border, all below the Putnam Hill (gray) limestone are buried beneath the surface.

The coal is so accessible upon the hill-sides, that drifting is the universal method of mining. There are no shafts, and the few slopes at the mine entries are solely for affording better screening and storing facilities. The drainage is always by ditches in the entry; an adverse dip is the commonest cause of the abandonment of entries. There is one case of the successful application of the siphon to mine drainage at Dr. Pomerine's mine at Berlin.

In the aggregate there is a large amount of good coal in Holmes county. While the thickness of the individual seams is not so great as at some other points, running from a maximum of 4 feet down to 2½ in the mines at present worked, there are nevertheless a large number of seams accessible, and the intervals between them are smaller than in localities to the southward and eastward. There are several fields that would sustain operations upon a large scale; while it is certain that from nearly every township in the county there will be, for a long time to come, a steady supply from the smaller veins, more than sufficient to meet the local demands.

At the present time only a single mine has railroad facilities for

shipping its coal. This is the Bowen mine, formerly Saunders', three miles south-west of Millersburg. A branch track from the Cleveland, Akron and Columbus Railroad brings the coal to Millersburg, whence it is shipped to various points between Akron and Columbus, or consumed upon the locomotives. The other mines of the county may be denominated country banks, their output being used for blacksmithing, generating steam, or domestic purposes within a few miles of the mine.

Some disastrous mining enterprises have been undertaken in this county, which have perhaps created a prejudice against the field. The responsibility for the failures, however, should be placed where it properly belongs, upon a lack of familiarity with the field, an inadequate preliminary survey, together with carelessness and extravagance in the management of the work. This does not demonstrate that these seams cannot be profitably mined upon the large scale.

Stratigraphical Order.

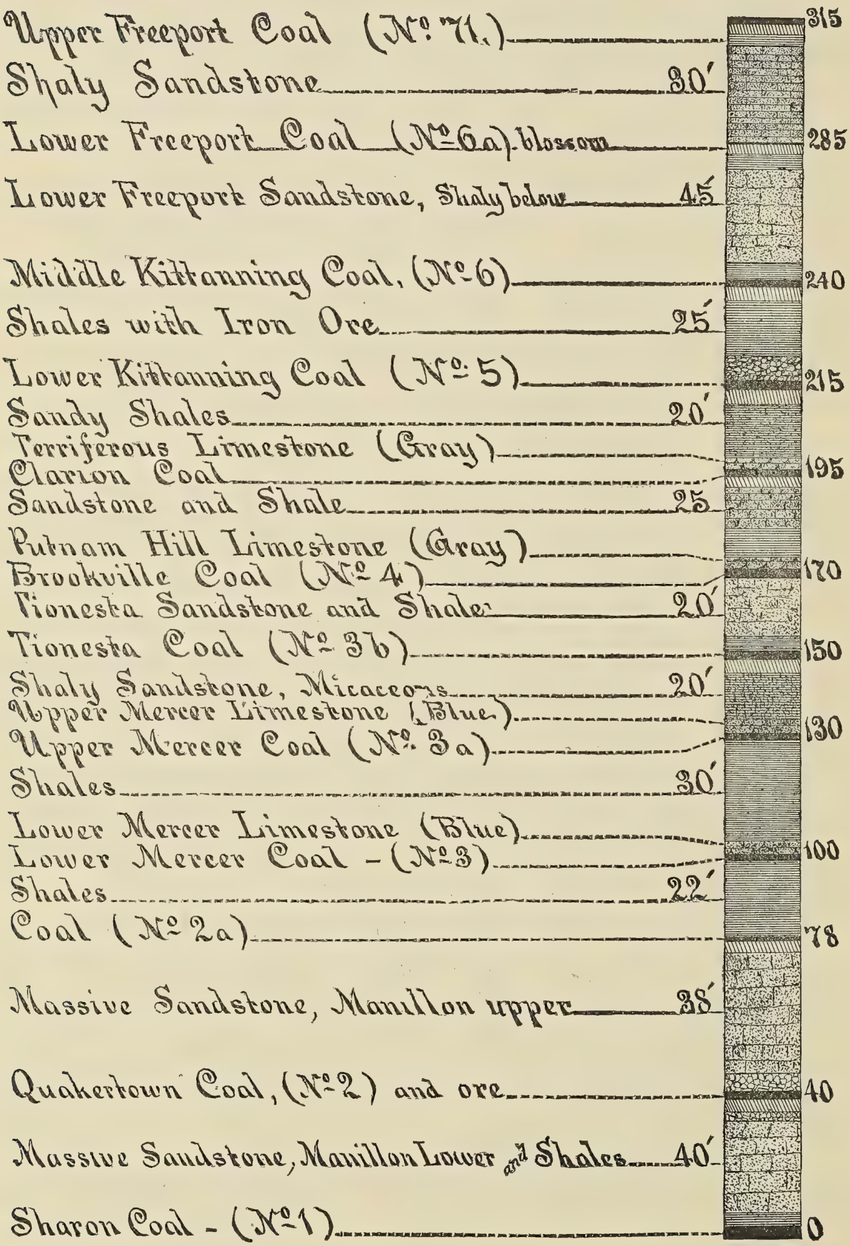
The general arrangement of the rocks and coal seams of the county is shown in Fig. I. The county may be divided into two somewhat distinct fields. The first, which occupies the south-eastern corner, is an extension of the Tuscarawas coal field, and should be considered with it. This field comprises the whole of German township, the southern part of Walnut creek, and perhaps the south-eastern part of Berlin, including the town of Berlin. In this field the most prominent geological elements are, 1st, the Putnam Hill (lower-gray) limestone; 2nd, the Lower Kittanning coal (No. 5), lying about 45 feet above the limestone, and, 3rd, the Middle Kittanning coal (No. 6), lying about 70 feet above the limestone. These identifications and intervals correspond with those of the adjacent portions of Tuscarawas county. For illustration, see Fig. V.

The second field comprises the rest of Holmes county, in which the lower strata are found, and some apparent changes occur in the upper strata, of which the most striking is that the Middle Kittanning coal (No. 6) appears at about 25 feet above a gray limestone instead of 70 feet, as in the first field, while the Lower Kittanning coal (No. 5) is missing. The best explanation that can now be given of this anomaly is as follows: The limestone in the latter case is the true Ferriferous (upper gray) which belongs about 25 feet above the Putnam Hill (lower

FIGURE I

GENERAL SECTION, HOLMES CO.

SCALE,— 50 FT. TO 1 IN.



sgray). This would reduce the interval between coal No. 6 and the lime tone to 45 feet. But the lower Kittanning coal (No. 5) is wanting in all this second field, and some twenty feet of shale carrying iron ore have gone with it, so that the interval between the limestone and the Upper Kittanning coal is reduced to about 25 feet. (See Fig. VII). The Putnam Hill limestone is by no means wanting in the second field, but the two are rarely seen together. A few cases, however, are mentioned hereafter.

Brief reference must be made to some horizons of the general section, Fig. I. The lowest coal (No. 1) is assumed to be the equivalent of the Sharon or Massillon seam, although it lies but 80 or 100 feet below the Lower Mercer (blue) limestone, whereas, in Stark and Mahoning counties, it is from 125 to 150 feet. In Fig. II it is seen close upon the characteristic Waverly shales, 98 feet below the limestone. The conglomerate is generally wanting.

The Quakertown coal or iron ore seam, of former reports, may be called No. 2. It lies between the upper and lower divisions of the coarse Massillon sandstone. In twelve different sections where measured at ranges from 52 to 71 feet below the Lower Mercer limestone, the iverage being 60 feet. It is shown in Figs. II and VI.

Twenty-two feet (15 to 28) below the Lower Mercer horizon, a coal seam appears which is designated 2*a*. It has been recognized in nine different sections, and is shown in Figs. II, IV, VI, VII. At some of these localities this may prove to be the Lower Mercer coal (No. 3), but if so, it will only emphasize the fact that the "blue limestone" is often the Upper Mercer, while the Lower Mercer is wanting.

The Lower Mercer coal (No. 3) and limestone (blue) constitute the most definite and persistent horizon in the county. They are invaluable as a starting point in identifying other horizons.

The Upper Mercer coal (3*a*) and limestone (blue, often flinty) are seen in the same section with the Lower Mercer coal and limestone at New Carlisle, and many places in southern Walnut Creek, at J. H. Harold's, in Central Point; at Moses Steele's, in south-eastern Mechanic; at Daniel Uhl's, in Central Mechanic, Fig. IV; at L. Allison's, on the Knox and Monroe line, and many other places. (See also Fig. III). The Upper Mercer Limestone can probably be found in every township where it is due, either as a limestone or a flint. My measurements make it from 17 to 38½ feet above the Lower Mercer, average 30.

In northern Salt Creek the Upper Mercer is the predominant limestone, as is shown by its interval below the Putnam Hill (gray) limestone (30 to 50 feet), and by the structure of its underlying coal (3*a*), as compared with that on Wayne Hill (compare Figs. X and XI, see Fig. III). The interval referred to runs as follows on adjoining farms: John Amsbaugh's, 31 feet; Josiah Slutz's, 41 feet; Henry R. Leeper's, 50 feet; Leonard Matthews', 50 feet.

The Tionesta coal (3*b*) is represented by the "sandstone vein," on Wayne Hill (Fig. III), near Fredericksburg, which has been called No. 6. The Putnam Hill limestone, which should appear about 20 feet above this coal, is cut away by a heavy sandstone, but on the opposite side of Apple Creek, at Joseph McElroy's, the limestone is 5 feet thick at its proper level, as is also the case in a section north of Holmesville, given by Dr. Newberry (Vol. II, chart No. 2).

The prominent gray limestone of the eastern and northern-central part of the county is considered the Putnam Hill limestone, while in the southern-central and western parts, both this and the Ferriferous are believed to be represented, though rarely together. [On limestones, see p. 817]. In some cases the Ferriferous and Putnam Hill are seen together, as at C. Fisher's and E. Snellenberger's, in southeastern German; M. Hochstetter's, east of Shanesville, Tuscarawas county; Jos. Finley's and Daniel Uhl's (Fig. IV), in Central Mechanic; A. Greenheiser's, adjoining A. A. Taylor's, in Knox (Fig. VI), and probably Wm. White's and vicinity, in southern Richland. The intervals vary from 15 to 41 feet; average, 25. Where only a single gray limestone is present, its elevation above the Lower Mercer (blue) limestone is the best guide we possess, the Ferriferous being due at about 100 feet, and the Putnam Hill at 60 to 80.

In western Monroe and Knox townships, a massive sandstone, 25 feet thick, comes between the gray limestones, and one or both of the latter are cut away, as at Thos. Miller's and A. A. Taylor's (Fig. VI). The same occurs on Wayne Hill (Fig. III). This sandstone (Hecla ?) caps the hills north of Black Creek, weathering out in great "boulders", but similar masses from the Massillon sandstone, 100 feet lower, abound in the valleys of Wolf Creek, Black Creek, the Killbuck, Indian Trail, etc. In Fig. III this heavy sandstone was supposed to cover coal No. 6, but the coal is evidently No. 4, as it is just below the level of the Putnam Hill limestone on the adjoining farm of A. Erenheiser, as

shown in the figure. On the farms adjoining westward the limestone has only its normal thickness of 3 or 4 feet. The upper coal seam, in Fig. VI, lying 30 feet above the Ferriferous limestone, is doubtless the true No. 6. This is the locality, 3 miles north of Black Creek, frequently referred to in previous volumes as carrying seven workable seams of coal. Their positions are here shown.

The relations of the Lower Kittanning coal are shown in Fig. V. It is missing, as before mentioned, in most of the county.

The Middle Kittanning coal (No. 6) lies 25 to 50 feet above the Ferriferous horizon, the smallest measures being in Killbuck township.

The Freeport sandstones fill the interval of 60 to 75 feet up to the Upper Freeport coal (No. 7). No good exposures of the Freeport limestones were observed, though fragments, which must be referred to these horizons, were met with in a number of places.

Coal Seams.

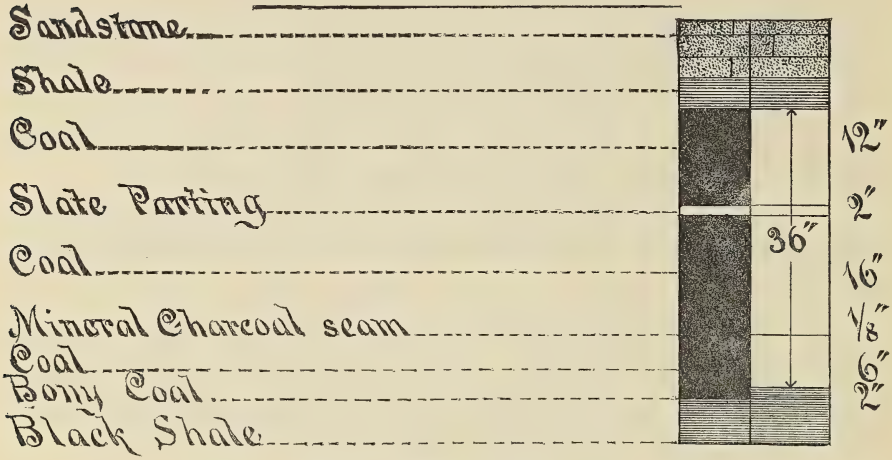
Sharon Coal (*No.* 1).

In the western half of the county this seam may be found above drainage, and has been opened at a good many points in Hardy, Prairie, and Monroe townships, the latter township constituting the most fertile field. The structure of the seam at Stephen R. Williams's, in Central Monroe, is shown in Fig. VIII to consist of an upper bench of 1 foot, and a lower one of 2 feet. The analysis of the benches, separately, by Professor Lord, is given below:

Sharon coal, S. R. Williams, Monroe township.	Upper bench.	Lower bench.
Moisture	5.62	6.57
Volatile combustible matter	41.65	41.44
Fixed carbon	48.25	47.49
Ash	4.48	4.50
Total	100.00	100.00
Sulphur	2.72	1.62

FIGURE VIII

SHARON COAL, (No 1) STEPHEN R. WILLIAMS.
MONROE TP.



SCALE 5 FT. TO 1 IN.

As compared with the other coals of the county, this shows excellent quality. The fixed carbon is reasonably high; the ash and especially the sulphur are low. The upper bench mines like a block coal, the lower is more irregular. The coal lights quickly, is somewhat cementing, and burns to a light cinder and gray ash with no clinkers. It is estimated that there are some 800 acres in Monroe township where this coal should be productive. Southward of S. R. Williams it is mined by Isaac Williams, westward by Wm. Mackey, on lot 28, where it is 2½ to 3 feet thick, with a shale parting near the middle, and northward by Smith and James Martin. Opposite Millersburg it is mined by Freeman and Bilderback, on Section 1, where it is 2½ feet thick, with a sulphurous parting of three inches. It is rusty, soft, and poor-looking, but both slack and coal find ready sale. Two miles north-west of Millersburg, on D. Snyder's farm, it is 20 inches thick, with a slate parting of two inches. It has been mined also by Joseph McElroy, in north-eastern Prairie township, and Franz Cooper, on Sand Run, in Hardy, and by several parties in Knox township. In Mechanic and Killbuck it may yet be found of workable thickness.

Quakertown Coal (*No.* 2).

The Strawbridge cannel was formerly called No. 2, but as that is evidently No. 3*a* (see Fig. VII), the former number may be employed to designate the "iron ore" seam of former reports, which lies about 60 feet below the Lower Mercer limestone (blue), and 30 to 40 feet above the Sharon coal, which corresponds well with the Quakertown coal of Western Pennsylvania. The coal is from 1 to 2½ feet thick, and not mined. At Millersburg it was 18 inches thick, and 141 feet above the Killbuck flats. At E. M. Wheaton's, in northern Hardy, it is 2 feet thick; on Chas. Steele's, in western Hardy, it is 2½ feet thick, and at A. A. Taylor's, in Knox (Fig. VI), it is 2 feet thick. This is considered the equivalent of the "rider" vein over the Massillon coal in Wayne and Stark counties. It nowhere promises to be valuable.

Coal 2*a*.

At 15 to 28 feet below the Lower Mercer coal there is sometimes seen a two-foot vein of coal, which has yielded fuel for market, though on the whole it is of little value. A mile east of Millersburg it was mined on the farm of George Maxwell, where it consisted of two benches of 15 inches each, separated by ten inches of clay. At the excavation for the scales below the Bowen mine, 3 miles south-west of Millersburg, it consists of 2½ feet of cannel, lying 68 feet below the Strawbridge cannel. In western Monroe (Fig. II) it is 2 feet thick, splitting into thin laminæ, and of a brilliant black luster. At A. A. Taylor's, in Knox (Fig. VI), it constitutes the cannel vein, which has been mined both by stripping and drifting. The vein has here the following structure :

Bituminous coal	0′ 8″
Fire-clay	1′
Slate	0′ 4″
Cannel	1′ 10″

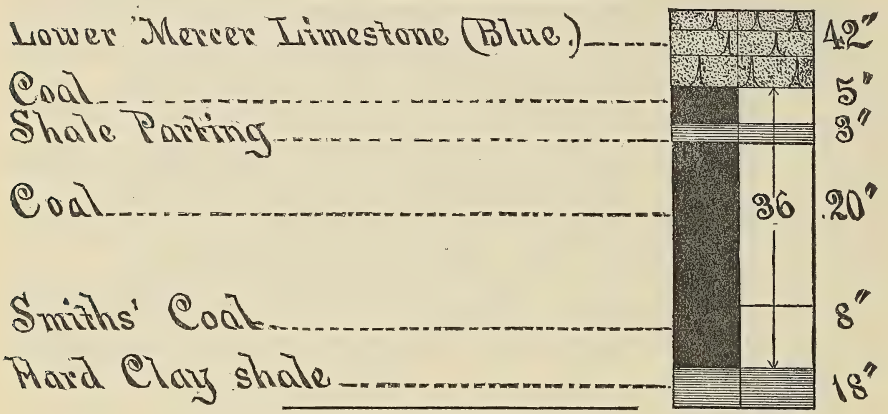
Work was abandoned here upon the discovery of thicker veins above.

Lower Mercer Coal (*No.* 3).

This coal is seen in its most favorable phase at the mines of Elias Mast and E. M. Wheaton, 3 miles north of Millersburg, where it is mined in considerable quantity. The excellent limestone roof is 2½ feet

FIGURE IX

LOWER MERCER COAL, (No. 3) E MAST AND E. M. WHEATON
HARDY TP.



SCALE, — 5 FT. TO 1 IN.

thick. The coal is 3 feet thick, with a shale parting of 3 inches, as shown in Fig. IX. The lower 8 inches is separated and highly valued as a smith's coal, and commands a higher price. The coal is a dry-burning semi-cannel, and comes out in block form. It is bright in luster, but with alternate stripes of duller coal, as in the block coals. It makes little slack; the ash is light and white, containing no clinkers. Its composition is given below:

Lower Mercer Coal, Elias Mast, Hardy Township (Lord).

Moisture	5.11
Volatile combustible matter	41.01
Fixed carbon	47.15
Ash	6.73
Total	100.00
Sulphur	2.90

In Monroe and Knox townships there is an area where this coal is well developed. At the mine of Henry Dagon, in eastern Knox, the seam reaches a greater thickness than elsewhere, showing the following section:

Lower Mercer limestone, 2 benches	2′	
Gray shale	6′	
Bituminous shale	0′	6″
Coal, upper bench	1′	8″
Clay	0′	6″
Coal, Middle bench	0′	10″
Slate parting	0′	2″
Coal, lower bench	1′	2″

This gives a total thickness of coal of 44 inches.

A mile north of this locality the seam was opened, but not pursued, on A. A. Taylor's farm (Fig. VI), and reported from 3½ to 6 feet in thickness. The larger figures could not hold over any great area.

At Washington Taylor's, in western Monroe, the same coal is mined. It is here 32 inches thick, the upper bench being 21 inches, the lower, 8 inches, with a 3-inch clay parting between.

The seam may be expected to hold a workable thickness over quite an area in western Monroe and eastern Knox, reaching southwards towards Black Creek or beyond. In this field, however, the thickness of the partings is a drawback, as observed by Mr. Read in Vol. III.

In central Mechanic township this seam has been prospected near Daniel Uhl's, by Levi Shaffer, where the seam, shown in Fig. IV, consists of two benches, the upper bench being 2 feet of cannel, and the lower 15 inches of bituminous coal, with a formidable parting of 1 foot of slate between them.

In south-western Walnut Creek, Jacob Mullett has prospected this seam, where it is 3 feet thick.

This seam probably possesses a larger acreage of accessible coal than any other in the county. It is often so deficient in thickness, however, that it is difficult to say whether it, or the Sharon coal, is entitled to rank next after the Middle Kittanning (No. 6) in value.

Upper Mercer Coal (No. 3a.)

In Killbuck township this seam is a cannel, locally thickened to 7 or 9 feet, as at the old Strawbridge mine (Fig. VII) and on the Cary and Urmson property on the eastern line of the township. A fair thickness of excellent cannel can doubtless be mined in both these localities whenever there is any call for it.

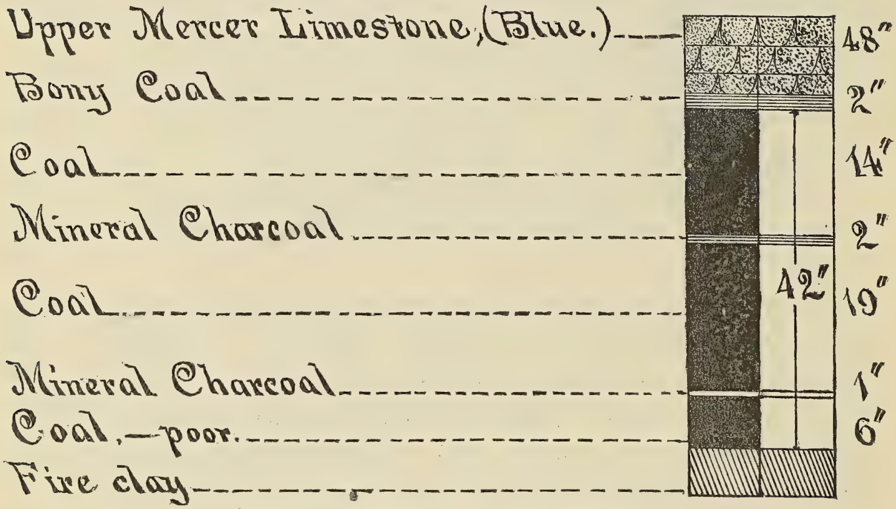
In Monroe and Knox townships this is called the "flint vein". On A. A. Taylor's (Fig. VII) it was 2½ to 3½ feet thick, in one bench,

with flinty limestone over it, and 8 inches of flint rock beneath it, as reported; the coal was fragile, streaked, full of sulphur, and melted down in burning.

In northern Salt Creek this seam is mined by John Amsbaugh, and has been opened by many others. Its structure is shown in Fig. X.

FIGURE X

UPPER MERCER COAL, (NO. 3 A.) JOHN AMSBAUGH, SALT CREEK TP.



SCALE 5 FT TO 1 IN.

The thickness runs from 3 to 3½ feet. The coal is soft, and requires careful mining to separate the dirt and pyrite. Below is an analysis:

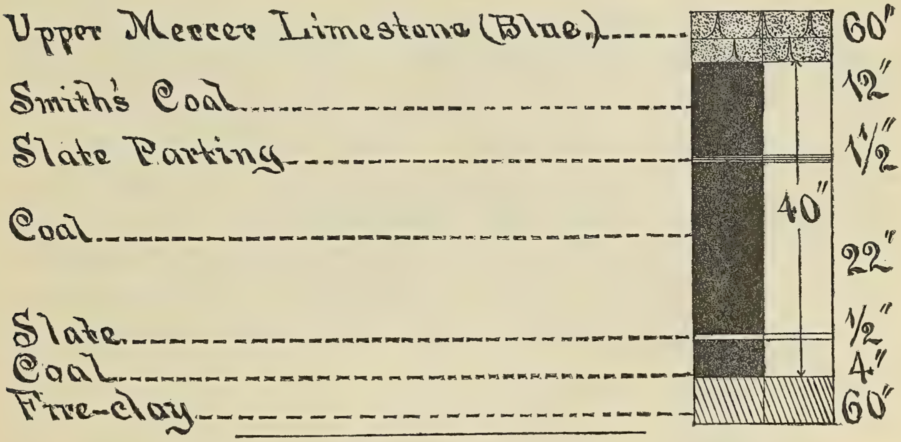
Upper Mercer Coal, John Amsbaugh, Salt Creek (Lord).

Moisture	3.80
Volatile combustible matter	43.45
Fixed carbon	42.80
Ash	9.95
Total	100.00
Sulphur	4.95

At Leonard Matthews', 1 mile east of the above, this seam consists of 2 feet of cannel and "bony" coal, above, and two feet of bituminous coal below. An impure, clayey limestone, at least 2 feet thick, underlies the fire-clay at this point.

FIGURE XI

UPPER MERCER COAL, (No. 3A.) JOSEPH REDETT, PRAIRIE TP.



SCALE 5 FT. TO 1 IN.

On the northern line of the county, in Prairie township, this coal constitutes the "limestone" seam, mined by Joseph Redett. (See Figs. III and XI). The limestone roof is 5 feet thick; the coal is 3 to 4 feet thick, averaging 39 inches; the clay floor is 5 feet thick. The arrangement of benches and partings is similar to that at J. Amsbaugh's (Fig. X). The middle bench carries a good deal of sulphur and is troubled with soot veins from 0 to 2 inches thick. The upper bench is cleaner, and is used as a smith's and steam coal at Fredericksburg.

In Richland township this coal was opened by Wm. White, but it proved to be of poor quality.

Tionesta Coal (No. 3b).

This coal was formerly mined and shipped by rail at Fredericksburg, near the north line of Prairie township.

It is the "sandstone vein" of Wayne Hill (Fig. III), and was $3\frac{1}{2}$ to $4\frac{1}{2}$ feet thick over a limited area, which is mined out. Around the margin, 32 inches of good coal remain, lying in one bench, and now mined on Joseph Redett's farm. The coal is a cementing, purple ash coal, contains much sulphur, and is apt to attach to grate bars. This is the only place known where it is worth mining. On Rev. Mr. McCartney's, adjoining A. A. Taylor's, in Knox township, it was

opened, and consisted of two benches of ten inches each, with ten inches of shale between them. (Fig. VI.)

Brookville Coal (*No.* 4).

This coal and the overlying Putnam Hill (gray) limestone, are exposed in perhaps every township of the county. The two are sometimes mined together for the manufacture of lime, as at Geo. Maxwell's and Samuel Stirlen's in Hardy, H. J. Asire's in Mechanic, and elsewhere. The coal is from one to two feet thick, of poor quality, but sufficiently good for burning lime. An exception should be made for this seam in Knox township at A. A. Taylor's, where, although only two feet thick, it has been worked considerably on its own account, and is considered of excellent quality. It was not accessible for analysis.

Clarion Coal.

This coal lies directly under the true Ferriferous (upper gray) limestone. It is difficult at some points, in the present state of our knowledge, to distinguish with certainty between this horizon and that of the Brookville, which is due some 20 or 30 feet lower, and more investigation is needed upon the relations of these two coals and limestones. The coal formerly mined by Daniel Shields, just west of the Bowen mine, is doubtless the same as that shown in Fig. VII, as the Clarion; but at both these points the Mercer limestones are missing. The coal, where mined, was 20 to 24 inches thick, and of rather poor quality. This horizon, at many places in the county, where most clearly exposed, has a thick bed of unusually white fire-clay under it.

Lower Kittanning Coal (*No.* 5).

This coal is present only in the south-eastern corner of the county. The seam, mined by Andrew Schrock, M. Zahner, and others, in south-eastern Walnut Creek, is referred to this horizon. In German township its outcrop is constant, and it is of workable thickness at Christian Fisher's and Christian Gerber's, under the black band ore, at George Domer's and elsewhere. On Noah Slaubach's, near Farmerstown, it proved too thin and was enveloped in a very tough sandstone.

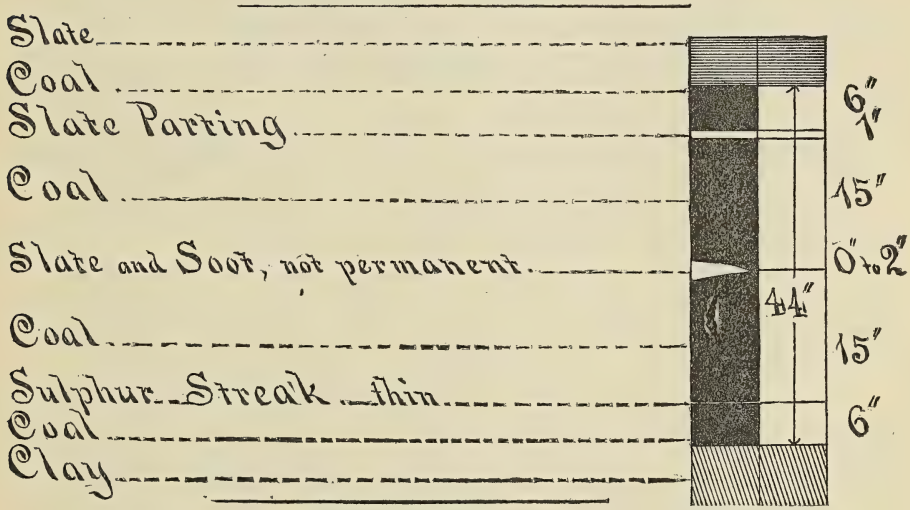
At John Croft's, in south-western German (Section 24), there is either a duplication of this seam, or, more likely, a close approach (2

feet) of the Lower and Middle Kittanning coals to each other, as is the case in some mines near Buena Vista, just over the line. The upper vein is here (Croft's) 4 feet thick, and the lower 3 feet, as reported.

At Andrew Schrock's, in Walnut Creek (Section 24), the coal is $3\frac{1}{2}$ to 4 feet thick, and its structure is shown in Fig. XII. The sulphur and mineral charcoal streaks near the center are not permanent. Below is an analysis:

FIGURE XII

LOWER KITTANNING COAL, (No. 5) ANDREW SCHROCK
WALNUT CREEK TP.



SCALE, 5 FT. TO 1 IN.

Lower Kittanning Coal, A. Schrock, Walnut Creek (Lord).

Moisture	4.49
Volatile combustible matter	42.50
Fixed carbon	47.27
Ash	5.74
Total	100.00
Sulphur	3.41

These figures show about the average quality of the seam.

At M. Zahner's, on the eastern line of the township, limestone guides are missing, but the coal now worked is probably the Lower

Kittanning. It is 3 feet thick, in one bench, but with sulphur partings, from 2 inches to nothing, sometimes appearing in the middle of the vein. The ash is purple. The shales above carry shell ore, and 30 feet above it the Middle Kittanning, a white ash coal, was formerly mined.

The productive area of this coal is probably limited to German, Walnut Creek and Berlin townships.

Middle Kittanning Coal (*No.* 6).

This seam is by far the most valuable and accessible in the county. It may be said to lie in all the high hills in the southern half of the county, and to retain the characteristics which it has in other counties. It is a cementing coal, often with a purple ash; it contains a large percentage of sulphur, but makes a good steam and domestic coal.

In German township the following mines may be mentioned among others:

Yagley (formerly Troyer and Dietz)	Sec. 6	R. 4
Noah Slaubach	" 10	R. 4
J. Slaubach	" 10	R. 4
Valentine Hershberger	" 9	R. 5
Alex. Hochstetter	" 9	R. 5
D. Erb	" 6	R. 5
John Croft	" 24	R. 5
J. Snellenberger	" 24	R. 4

The coal here lies 60 to 80 feet ubove the Putnam Hill limestone, and 25 to 40 feet above the Lower Kittanning coal. It is $2\frac{1}{2}$ to $3\frac{1}{2}$ feet thick. At Mr. Yagley's it lies in one bench without partings, the upper 6 inches being cannel, and the ash white. At Noah Slaubach's it is 3 feet thick, including the upper 6 inches of cannel, but thickens in the hill. It has a purplish ash. At V. Hershberger's it is 28 to 36 inches thick, and should hold over 50 acres. The annual output here is 16 to 17 thousand bushels. The coal has a very good reputation in the neighborhood. Its physical qualities are excellent, though the analysis, herewith given, shows no specially strong points:

Middle Kittanning Coal, V. Hershberger, German Township (*Lord*).

Moisture	4.51
Volatile combustible matter	44.86
Fixed carbon	44.55
Ash	6.08
Total	100.00
Sulphur	4.68

It will be observed that the percentage of fixed carbon here falls below that of the volatile and combustible matter.

Alex. Hochstetter's mine is close by, on the opposite side of the hill, and the quality of the coal cannot vary much from the preceding.

At John Croft's the two seams, already mentioned, representing one or both the Kittannings, lie about 50 feet above the Putnam Hill limestone, and close together. The mine was not accessible at the time it was visited.

At M. Zahner's, in south-eastern Walnut Creek, the upper vein, considered Middle Kittanning, was abandoned for the lower, which was better. The upper was 33 inches thick, was light and burned fast, leaving a white ash like wood.

At Aaron Mast's, adjoining the above, the Kittanning coals are reported to have run near together and then separated.

Henry Miller's coal, on section 24, Walnut Creek, is reported as 30 to 33 inches thick, has a purple ash, and has been worked since 1877. Several other openings have been made in this part of the township.

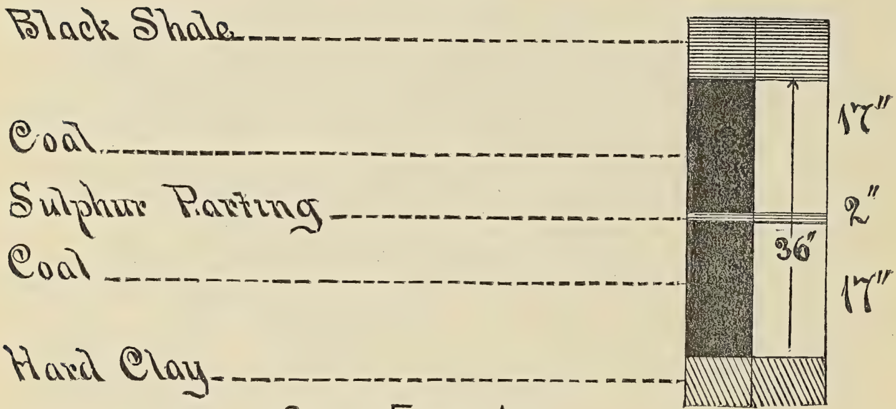
In north-western Walnut Creek, on Indian Trail, this seam is mined by Moses Hochstetter, Adam Scar, Samuel Weaver, and others, while the seam extends southward toward Walnut Creek, and eastward to the vicinity of Weinsberg. The coal averages 3 feet thick, has a purple ash, and is of excellent quality at Adam Scar's, as the following analysis, by Professor Lord, will show:

Middle Kittanning Coal, A. Scar, Walnut Creek.	Lower Bench.	Upper Bench.
Moisture	5.63	5.55
Volatile combustible matter	39.59	41.41
Fixed carbon	49.88	49.87
Ash	4.90	3,17
Total	100.00	100.00
Sulphur	2.54	2.35

These figures indicate the very best phase of the Middle Kittanning coal, and if the average output can keep up with them no more could be asked. The percentages of ash and sulphur are low, while that of the fixed carbon is near the maximum for this seam. The benches are of about equal thickness, with a two-inch sulphurous parting between them, as shown in Fig. XIII. The lower bench is used as a black-

smiths' coal. The roof is of strong slate, and the floor of hard clay The coal is not strong physically. It is mined by wedging down, after bearing in below—the common method for this seam.

FIGURE XIII
KITTANNING COAL (No. 6) A. SCAR,
WALNUT CREEK TP.



SCALE, 5 FT. TO 1 IN.

At Berlin village there are two coal seams, which lie, after allowing for considerable local dip, about 35 and 75 feet above a gray limestone. They have been designated Nos. 6 and 7. The upper is probably 6*a* if the lower is 6. The similarity of the section, however, to those in German and Walnut Creek townships (see Fig. V), raises the question whether these are not the Kittanning coals, 5 and 6. But as sufficient examination of the region has not been made to warrant a change, the lower seam will be discussed as No. 6. It has a sandstone roof, though shales sometimes intervene. The ash is purple, and there is an inconstant middle parting of sulphurous matter. It is 33 inches thick, and is mined by Dr. P. P. Pomerine and George Hott. Dr. Pomerine's mine was sampled with the following result:

Middle Kittanning Coal, Dr. Pomerine, Berlin (Lord).

Moisture	4.41
Volatile combustible matter	44.05
Fixed carbon	45.17
Ash	6.37
Total	100.00
Sulphur	4.74

The coal is strongly cementing, forms clinkers, and is not strong physically, yet makes a valuable domestic fuel. The large local dip and occasional sandstone horsebacks from above have given trouble in this region.

The upper vein was mined for a short time by G. Hott. It was 30 inches thick. The hills in this region rise from 100 to 130 feet above the gray limestone, and quite a large area south and east of Berlin should carry these coals.

In Mechanic and eastern Killbuck townships there is a productive area of Middle Kittanning coal, where it averages $3\frac{1}{2}$ feet thick, and is mined by John Purdy, Esq., Levi K. Uhl, Wm. Galion and Cary and Urmson, the latter parties owning the Shepler or Holmes County Company property. At J. Purdy's the coal is 3 to $3\frac{1}{2}$ feet thick, with a cannel layer 2 to 6 inches thick a little above the middle. It is bright and black when freshly mined, but the pyrite is apt to oxidize upon exposure to a white bloom of copperas. There is some mineral charcoal near the top. Below is an analysis :

Middle Kittanning Coal, J. Purdy, Mechanic Township (Lord).

Moisture	4.10
Volatile combustible matter	42.47
Fixed carbon	42.24
Ash	11.19
Total	100.00
Sulphur	5.08

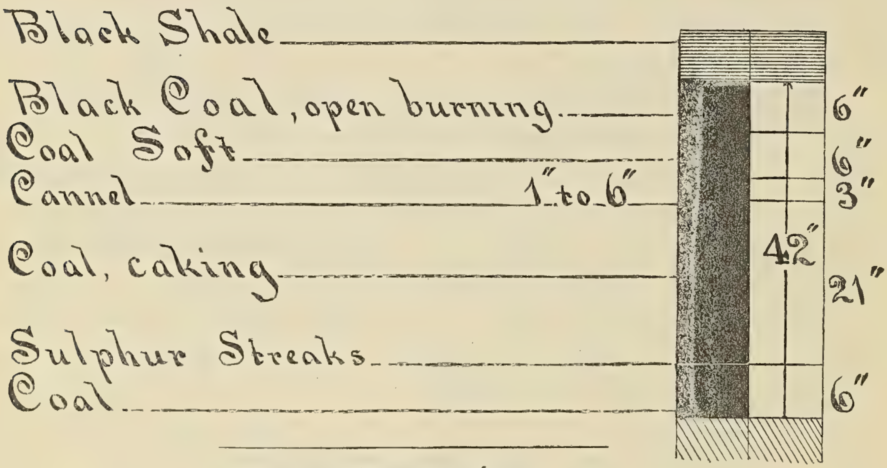
The percentage of ash is here large. Probably it can be mined so that these figures will be reduced.

At Levi Uhl's the face of the coal shows 4 feet of thickness, in three benches, several inches of cannel coming in at 3 feet from the bottom, and a slate parting one foot from the bottom.

On the Cary and Urmson property the coal is 40 to 48 inches thick, averaging 42. Its structure is shown in Fig. XIV, though it varies in different parts of the mine. The upper bench, above the cannel, is partly an open-burning block coal, and partly tenderer, with some mineral charcoal. From the analysis given below, the upper bench appears to differ but little from the average of the seam, excepting in the percentage of sulphur.

FIGURE XIV

MIDDLE KITTANNING COAL (No. 6)
CARY & URMSON, KILLBUCK TP.



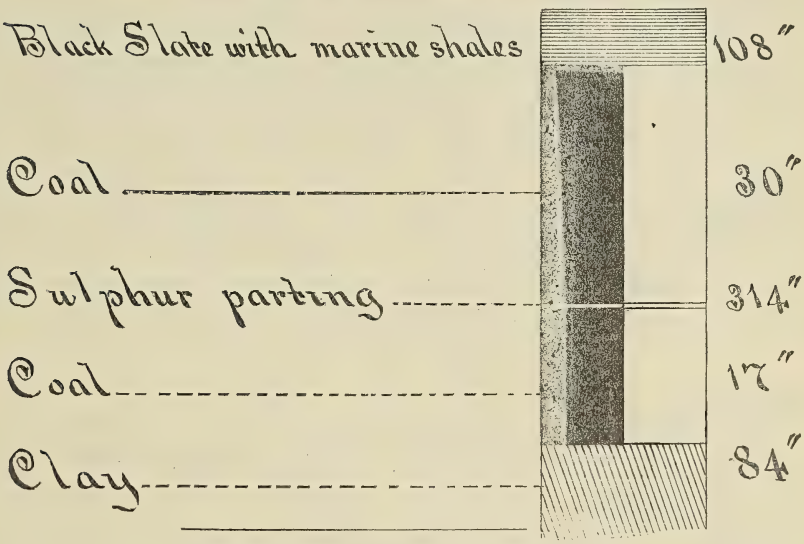
SCALE,– 5 FT. TO 1 IN.

Middle Kittanning coal, Cary and Urmson, Killbuck (*Lord*).	Upper bench.	Average of seam.
Moisture	4.37	5.50
Volatile combustible matter	43.82	42.03
Fixed carbon	44.68	44.59
Ash	7.13	7.88
Totals	100.00	100.00
Sulphur	5.08	3.86

In the field just described, this seam lies 80 feet below the summit of the hills, and about 300 feet above the track of the Cleveland, Akron and Columbus Railroad. A branch track is graded up Shepler Run to the foot of the incline from the Cary and Urmson openings, made by the old Holmes County Company. Under judicious management a re-equipment of the mines for work on a large scale could doubtless be made profitable. The acreage is considerable, Messrs. Cary and Urmson alone owning the mineral on 700 acres, a fair proportion of which is high land carrying No. 6 coal.

FIGURE XV

MIDDLE KITTANNING COAL (No. 6)
E. AND D. BOWEN, HARDY TP.



SCALE,—5 FT. TO 1 IN.

Across the Killbuck, in the north-western corner of Hardy township, is situated the Bowen mine, where coal has been dug for 50 years. For the structure of the hills and of the coal seam, see Figs. VII and XV. The seam here averages about 4 feet in thickness, ranging from 3 to 4½. The pyrite streaks shown in Fig. XV are not everywhere persistent. The lower bench is considered the best. Both benches thicken, and the quality improves where the seam is thickest, as reported. Two analyses are given—one of the average run of the mine, and the other of picked samples:

Middle Kittanning Coal, Bowen Bros., Hardy (*Lord*).	Average of mine.	Picked samples.
Moisture	5.41	7.44
Volatile combustible matter	42.39	41.42
Fixed carbon	45.38	48.61
Ash	6.82	2.53
Totals	100.00	100.00
Sulphur	4.72	2.28

These widely different figures show the use of proper sampling. The daily production of this mine, in winter, is about 30 tons, requiring 15 miners. The coal is shipped by the Cleveland, Akron and Columbus Railroad to Millersburg and various other points, where it is in good demand as a steam and domestic coal. The mining is principally done upon the 100 acres owned by Anson Myers, of Millersburg. The hills northward and eastward also carry the coal, and it is mined by John Howe, Charles Steele and Wm. Lisle. Judge Armor's hill is exhausted.

In Knox township, the upper or "four foot vein" at A. A. Taylor's, 2½ miles south of Nashville, is regarded as Middle Kittanning, for reasons already stated. It shows sulphur streaks at sixteen inches from the bottom. This locality is practically exhausted.

Freeport Coals (*Nos.* 6*a and* 7).

The Freeport coals have little, if any, value in this county. The Upper Freeport seam, shown in Fig. VII, has a thin cover and limited area, being confined in this case to a single hill. The same remarks will apply to north-eastern Killbuck, where it is 2½ feet thick, and found at 73 and 76 feet above the Middle Kittanning. The upper seam at Berlin, which may be one of the Freeport coals, has better cover and considerable area, and may be reckoned as valuable.

NOTE.

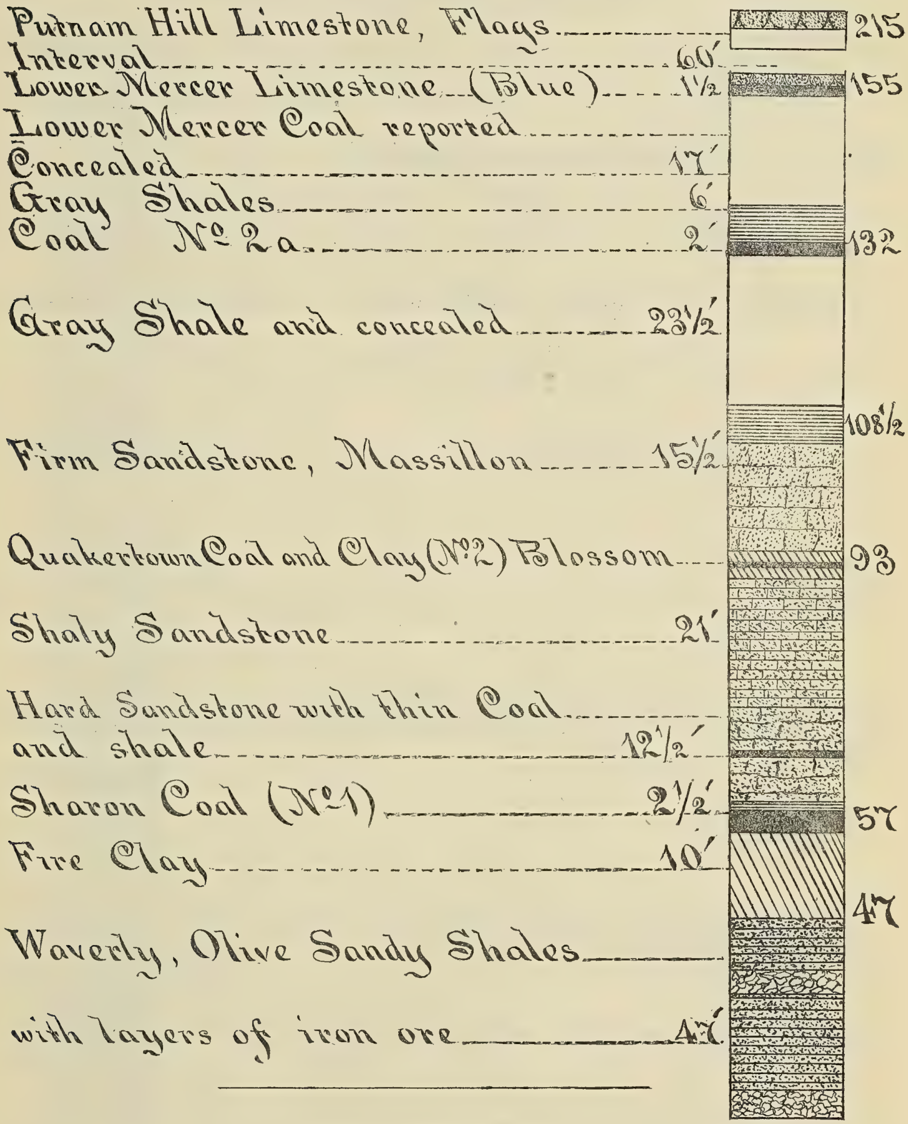
On map No. 4, accompanying the present volume, the boundary of the Lower Coal Measures in Holmes county is represented, and also the areas occupied by the Kittanning coal. The first-named boundary is taken from Newberry's map. It is a matter of regret that Professor Wright could not have had these latter results before him in the making of his report, but they were not obtained until after his work was completed. With these facts in hand, a few of his statements might have been modified.

The outlines of the Kittanning horizon in the county will surprise every one who examines them who has also a knowledge of the geology of the county. In no other district of the State has this formation suffered so extensive erosion, at least without being altogether removed. Originally covering a full half of the area of the county, nothing is now left but long snake-like ridges, seldom a mile in breadth, and disposed in fantastic and unexpected shapes. The acreage is very much less than has been generally held by those best informed as to the county, but numerous localities can be selected in which a mine could easily tap an area of 600, 800 or 1,000 acres.

E. O.

FIGURE 11

SECTION AT MRS. S. ARMSTRONG'S (MOTE'S MINE)
MONROE TP.

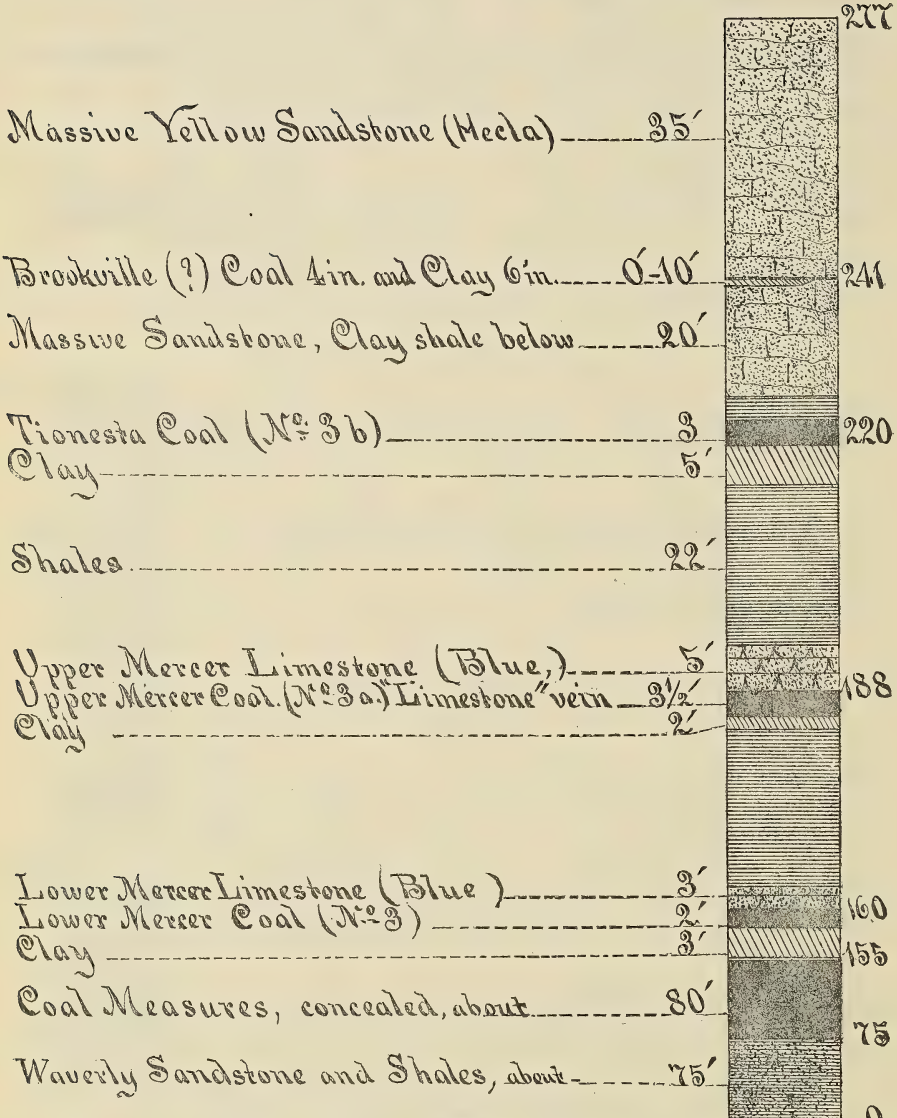


SCALE 50 FT. TO 1 IN.

FIGURE III

SECTION AT WAYNE HILL PRAIRIE TP.

SCALE 50 FT. TO 1 IN.



RAILROAD 1½ MILE SOUTH OF FREDERICKSBURG.

FIGURE IV

SECTION AT DANIEL UHL, MECHANIC TP.

50 FT. TO 1 IN.

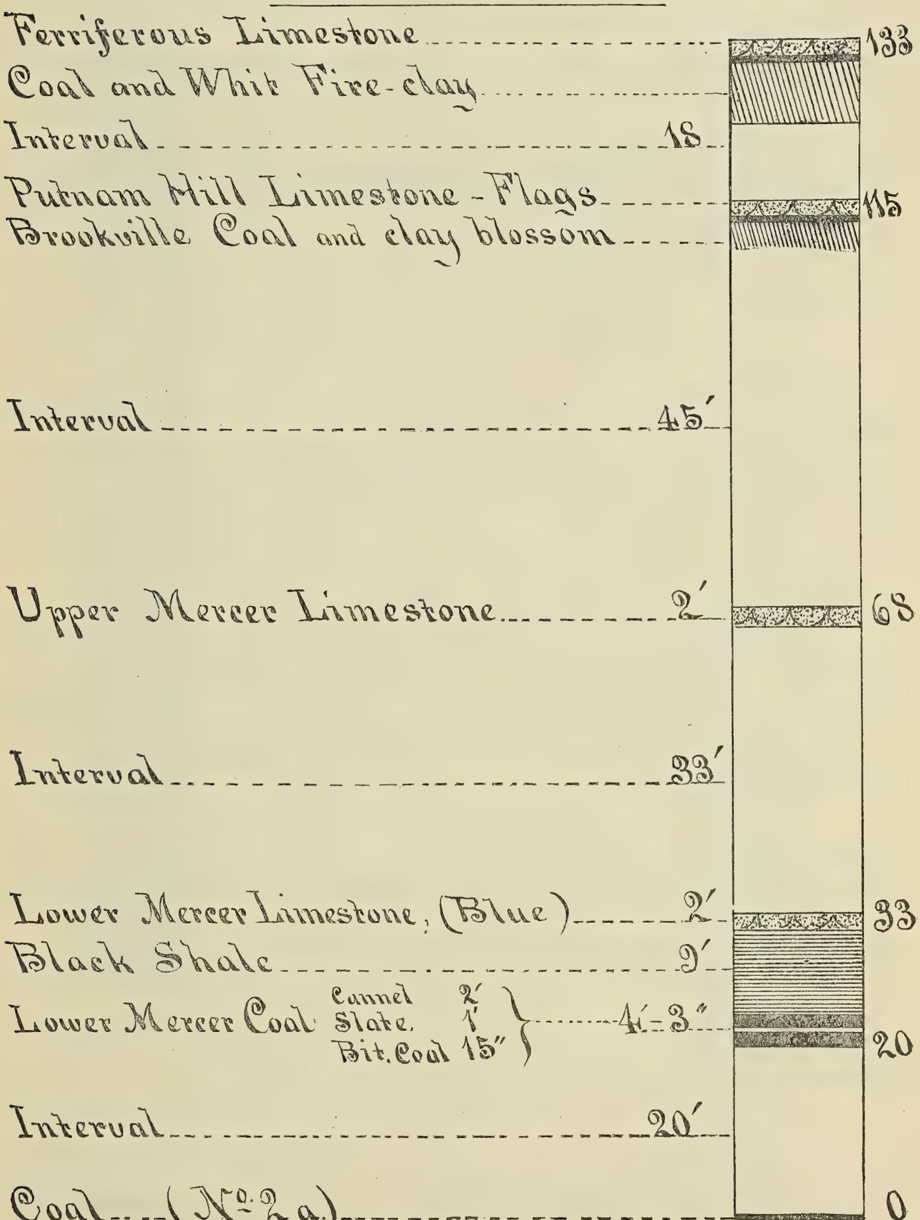


FIGURE V

SECTION AT GEO. DOMER'S GERMAN TP.

SCALE, 50 FT. TO 1 IN.

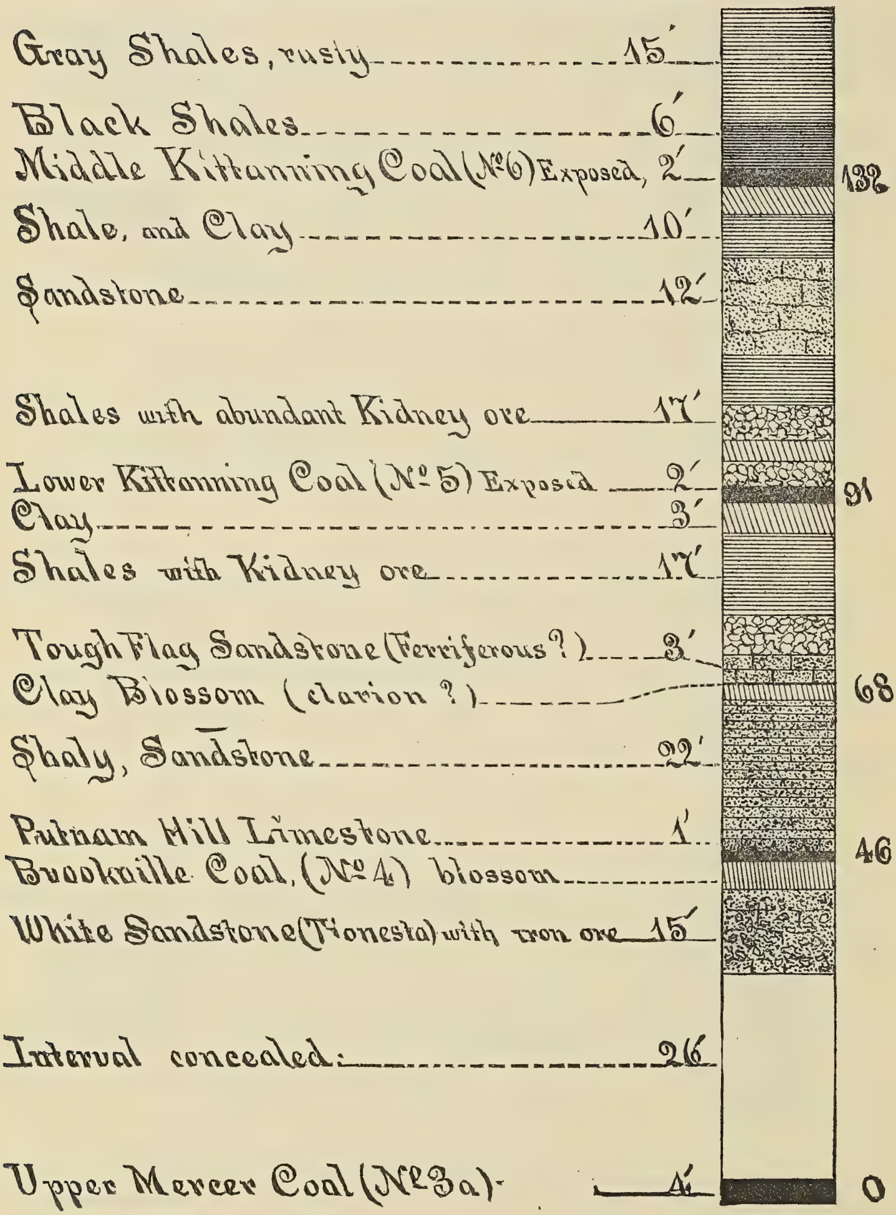
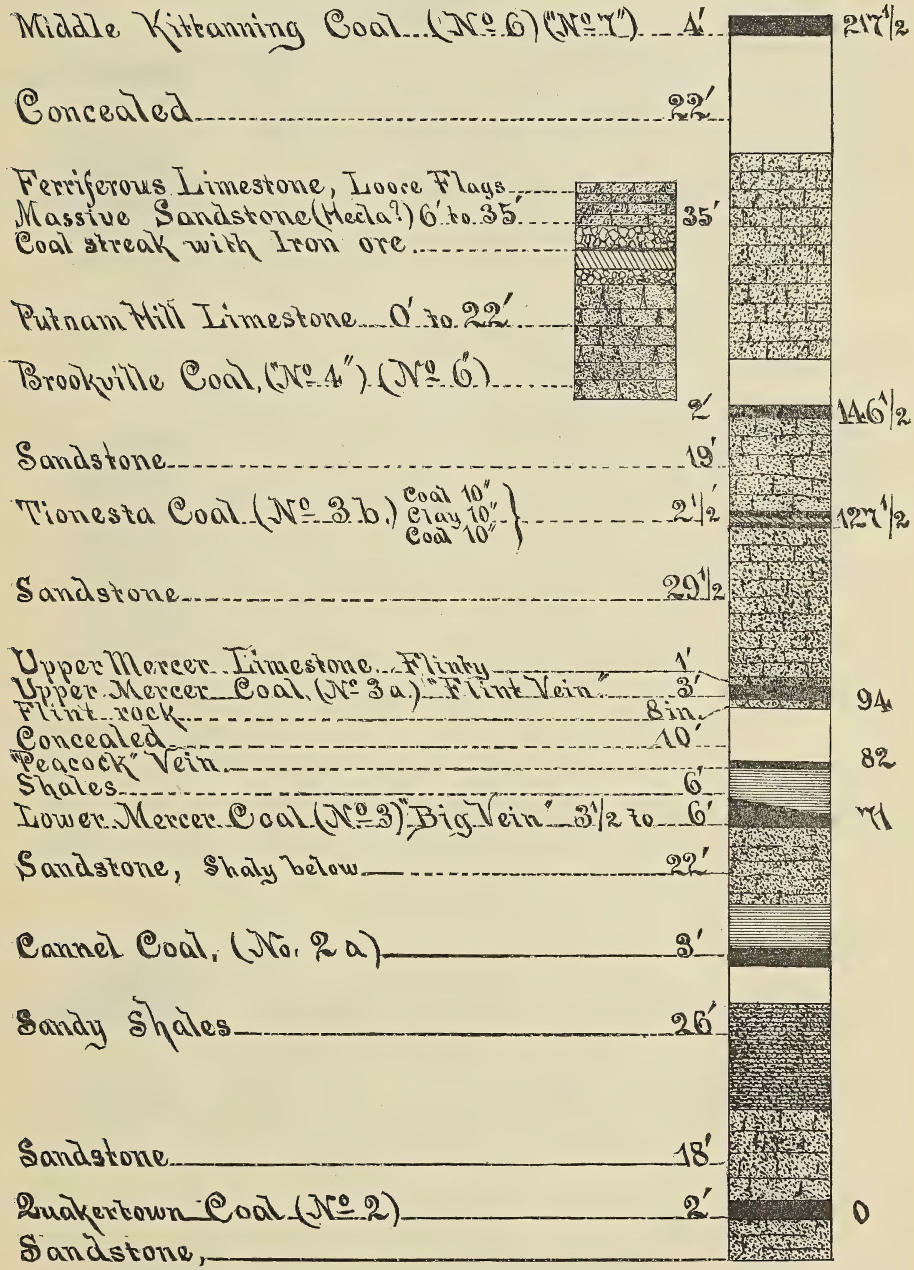
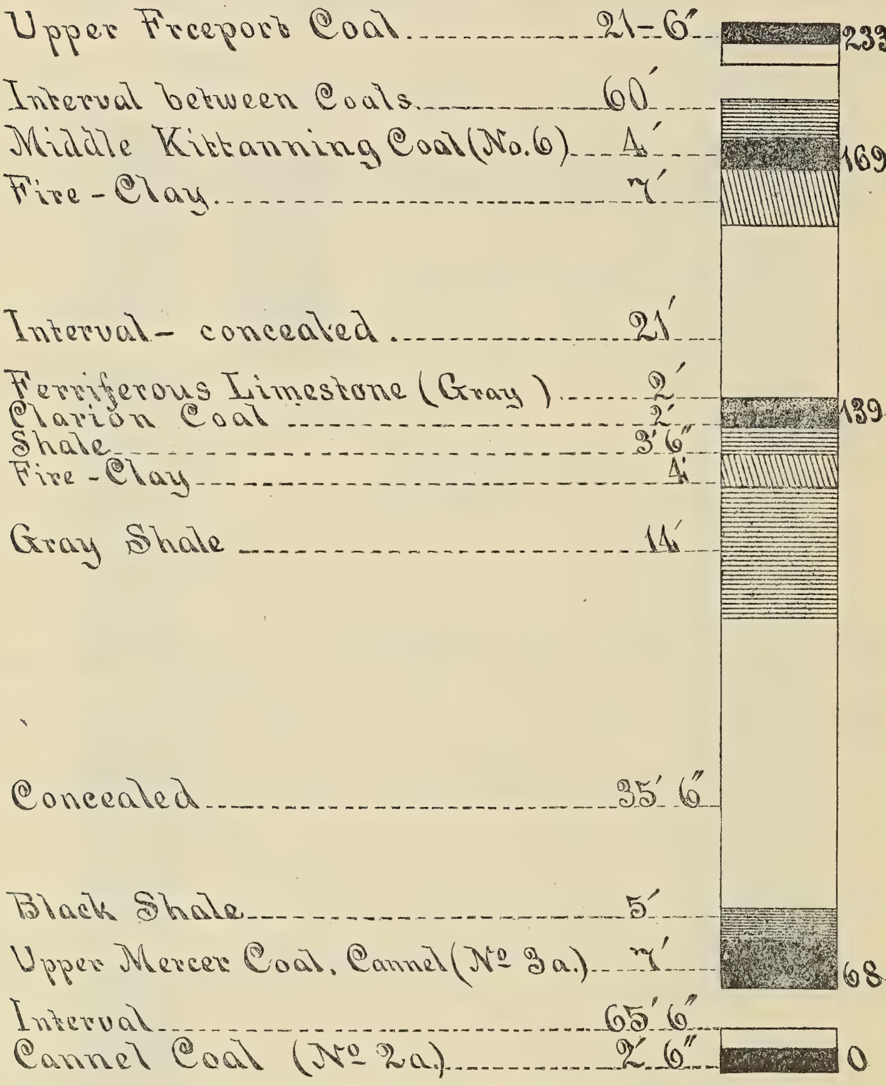


FIGURE VI
SECTION AT A.A. TAYLOR'S KNOX TP.



Scale 50 ft. to 1 in.

FIGURE VII
SECTION AT BOWEN'S MINE, (SAUNDERS)
HARDY TP.



SCALE, 50 FT. TO 1 IN.

CHAPTER XIV.

THE COAL SEAMS OF THE LOWER COAL MEASURES OF OHIO—Continued.

MINES OF COSHOCTON COUNTY.

By Edward Orton, Jr.

A general review of the stratigraphical geology of this county, together with a brief description of the development of its minerals may be found in the report of Prof. J. T. Hodge (Vol. III, Ohio Geological Survey, pp. 562–595). Since the publication of that report (1872), its coal fields have undergone considerable development; a description of their present condition will form the subject-matter of this report.

Though limestone, sandstone for building purposes, iron ore and fire-clays, are found in all parts of the county in limited amounts, yet they are of small economic importance, and are of interest mainly as geological landmarks.

The number and position of the coal veins and the more important of the other strata exposed in the county may be seen in the following general section:

General Section.

No.	Name.	Equivalents.	Thickness.
18.	Upper Freeport Coal and Clay	(No. 7 of Newberry)	variable.
17.	" Limestone	....	"
16.	Lower Freeport Coal and Clay	(No. 6*a* of Newberry)	"
15.	" Limestone	(Buff Limestones)	"
14.	" Sandstone	(Heavy and Massive, pebbly)	80 feet.
13.	Middle Kittanning Coal and Clay	(No. 6 of Newberry)	3 to 6 ft.
12.	Black Limestone, or Marble	(Local)	———
11.	Lower Kittanning Coal and Clay	(No. 5 of Newberry)	local.
10.	Putnam Hill Limestone and Ore	(Gray Lime of Newberry)	4 to 8 ft.
9.	Brookville Coal and Clay	(No. 4 of Newberry)	2 to 5′.
8.	Tionesta Coal	(No. 3*b* of Newberry)	local and thin.

7.	Upper Mercer Limestone	(Flint Horizon)	3 to 6 ft.
6.	" Coal and Clay	(No. 3 B of Newberry)	1 to 9 ft.
5.	Lower Mercer Limestone	(Zoar of Newberry)	1 foot.
4.	" Coal	(No. 3 of Newberry)	thin.
3.	Massillon Sandstone—Heavy	....	100 ft.
2.	Sharon Coal	(No. 1 of Newberry)	thin and uncertain.
1.	Waverly Group, flagstones	(Shales and Conglomerate)	200 feet.

These elements cannot all be found in any one section, but in some particular locality in the county each is a well-marked horizon. The differences of level between these elements vary greatly; a characteristic section for all the central part of the county is given on page 95 of this volume from the Beech Hollow mines near Coshocton.

Coal Seams.

The coal seams which are of economic importance are the Upper Mercer (No. 3*a*), the Brookville (No. 4), the Lower Kittanning (No. 5), and the Middle Kittanning (No. 6). Coshocton county has but small importance at the present time as a coal producing center, only 80,000 tons being credited to it in 1883. The railroad trade is confined to a few banks only, but these are of very fair capacity; the rest of the county at present supplies the demands of home consumption alone, waiting increased facilities and increased inducements to open up in the large way. In Tiverton, Newcastle, and Perry townships, on the western edge of the county, many efforts have been made to use the local streaks of the so-called No. 1 or Sharon coal, which lies at the top of the Waverly and at the bottom of the heavy Massillon sandstone. In no case has any degree of success been attained, though banks have been kept running for a year or two at a time. The coal is thin, of poor quality, and constantly liable to sandstone "cut-outs."

The *Lower Mercer* Horizon furnishes here, as elsewhere, one of the most constant and certain guides in a study of stratigraphical order, but its usefulness is confined to that. In no instance in Coshocton county has coal from this horizon been found thick enough to mine, by the investigations of the present survey.

The Upper Mercer Horizon.

The Upper Mercer Horizon, though not so very stable as an element in the scale, is developed in one district in a very noticeable way, and will doubtless become a source of some revenue to the county.

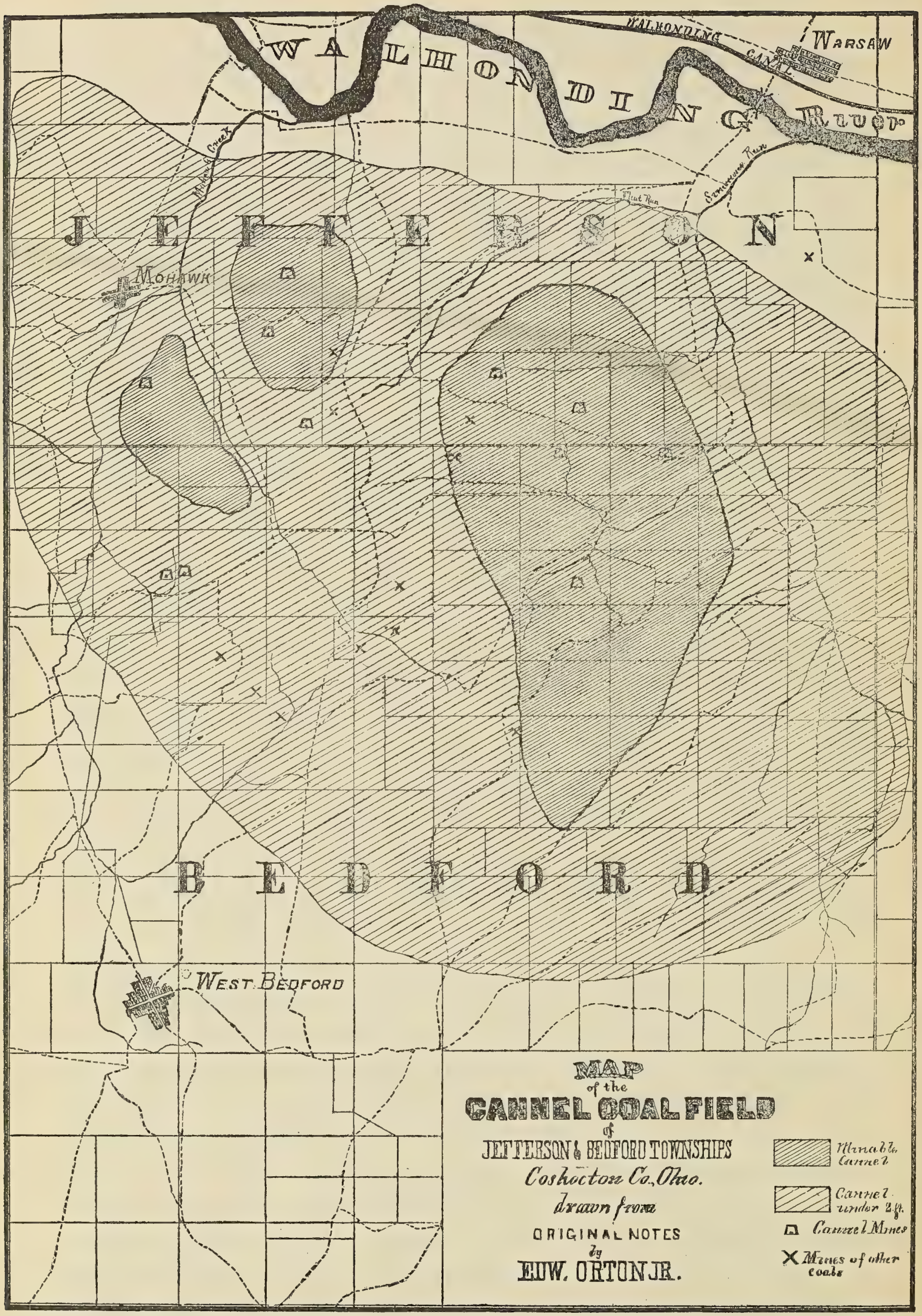
In Bedford and Jefferson townships, the limestone is found overlying a bed of cannel coal from 1 to 6 ft. thick, accompanied by from 1 to 4 ft. of bituminous coal. This is without doubt the finest proved deposit of cannel coal in the State, both as to area and thickness; as to quality, there are small bodies of cannel elsewhere, which are as good as this, though none excel it and none are so easily accessible, when railroad facilities are secured. The limestone of this horizon is found in a large part of the county with tolerable regularity; in some districts it does not appear at all. In all its showings, it is a blue, hard limerock, from 3 to 6 ft. thick, divided into a lower layer of homogeneous rock, and an upper layer of either solid flint or interlacing nodules of flint imbedded in a limerock matrix. As it is worn away by the atmospheric agencies, the upper or resisting layers overhang the more easily soluble ones beneath. This distinguishes it from the Lower Mercer, which is always a pure, uniform layer of blue limestone.

The Bedford Cannel Coal.

The importance of the Upper Mercer horizon is confined to the single field already mentioned, which is best known as the Bedford cannel coal field. The area covered by this deposit was made the subject of careful investigation, and forms the subject of the accompanying map. The boundaries of the ground covered by the formation itself, are included between the Walhonding river, on the north; Jackson township, on the east; Tunnel Hill, or the Coshocton and Bedford road, on the south, and Newcastle, on the west. The square area included between these limits is about 16,000 acres, but the curved outlines of the formation do not include over 12,000 or 13,000 acres.

Occasional outlines of the main body are found, but are of no value; two miles north of the Walhonding river, in Jefferson township, the cannel has degenerated into 7 ft. of a rich black shale, and in the eastern edge of Newcastle township an opening shows only 3½ ft. of an impure bone coal on this horizon. To the eastward, as far as Roscoe, reports are current as to the presence of this coal, but they are too indefinite to be depended on. At Roscoe there is a small local development of cannel on the horizon, but it is altogether improbable that it has any connection with the body of the coal 10 miles to the westward.

Inside the approximate boundary which fixes the feather-edges of the formation itself, are secondary lines which mark the areas of


WALHONDING RIVER
WALHONDING CANAL
WARSAW
JEFFERSON
MOHAWK
BEDFORD
WEST BEDFORD
MAP of the CANNEL COAL FIELD of JEFFERSON & BEDFORD TOWNSHIPS Coshocton Co., Ohio. drawn from ORIGINAL NOTES by EDW. ORTON JR.
Minable Cannel
Cannel under 2 ft.
Cannel Mines
Mines of other coals

valuable coal. These are three in number, and may be well seen in the accompanying map. From these areas as outlined on the map must still be subtracted that cut out by the drainage of the territory; diminished by this amount the area is estimated to be between 1,400 and 1,500 acres in extent.

The structure and character of the vein, as variously seen, will now be taken up.

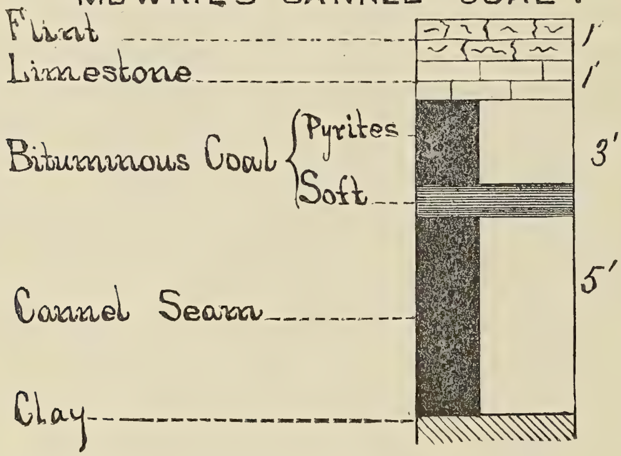
Beginning at the westernmost edge of the district, we find, about ½ mile south of Mohawk Village and the high hill which lies between the forks of Mohawk Creek, the mine of Jas. Givens. The mine is newly opened, and its best coal is not yet reached. The cannel was 6 ft. thick, sound and hard; not so conchoidal in fracture as seen in some other localities, and of a little less luster than usual. No test of its quality by general use had yet been made.

Crossing the east fork of Mohawk Creek and ascending the high hill to the east, we approach the banks of James and John Moore. They are situated about 1 mile east of Mohawk Village and in the small central area of mineable cannel indicated on the map. The bank of John Moore was worked on an extensive scale in former years, but has now been idle for a long time. It could be put into working shape with some little time and labor. The bank of Jas. Moore, or the northernmost of the two, is one of the old mines of the country, but is still open and serves during the winter months as a neighborhood bank. The coal is seen in one of its best exposures here; it is 6 feet thick as a regular and constant thing, and is overlain by 1 foot of soft bituminous coal, which affords ample opportunity for the miner to make his "*bearing in*". The coal mines without the use of powder, with hammer and wedge alone, into large solid blocks like quarry stone. They often come out so large as to be used by the country people as steps and horse blocks, being durable enough for that purpose. The mines have been worked on the single entry plan and have been somewhat damaged by poor mining, but the strength of the roof is proof against any ordinary abuse, and the mines are still in fair shape. Going eastward, the cannel thins down again; on the lands of Mr. J. Park Wheeler, extending down into Flint Run bottoms, the coal is present, but too thin to be valuable, but on the opposite side, on the lands of Mr. J. M. Creighton, the coal thickens up to a good height. Following the ridge road eastward, the banks of Messrs.

Mowrie on one side and Lyman on the other, appear. These two banks are in the largest body of the coal, and are also located in one of its best exposures. The structure is shown in the appended section, Fig. I:

FIGURE I

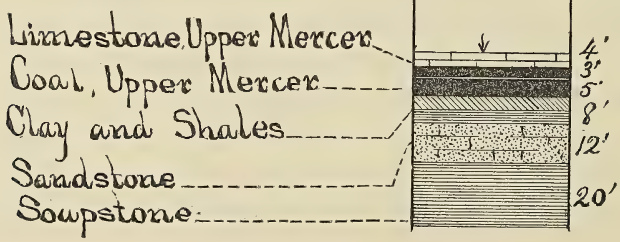
MOWRIES CANNEL COAL.



The cannel is firmer and harder at this bank than in any other now open. It is exclusively close-grained and curly, and its face and butt slips are so little defined as to make it necessary to use powder in mining. The bituminous coal is quite soft just over the cannel, but

FIGURE II

SECTION ON SHARPLESS, MOWRIE AND LYMANS FARMS.

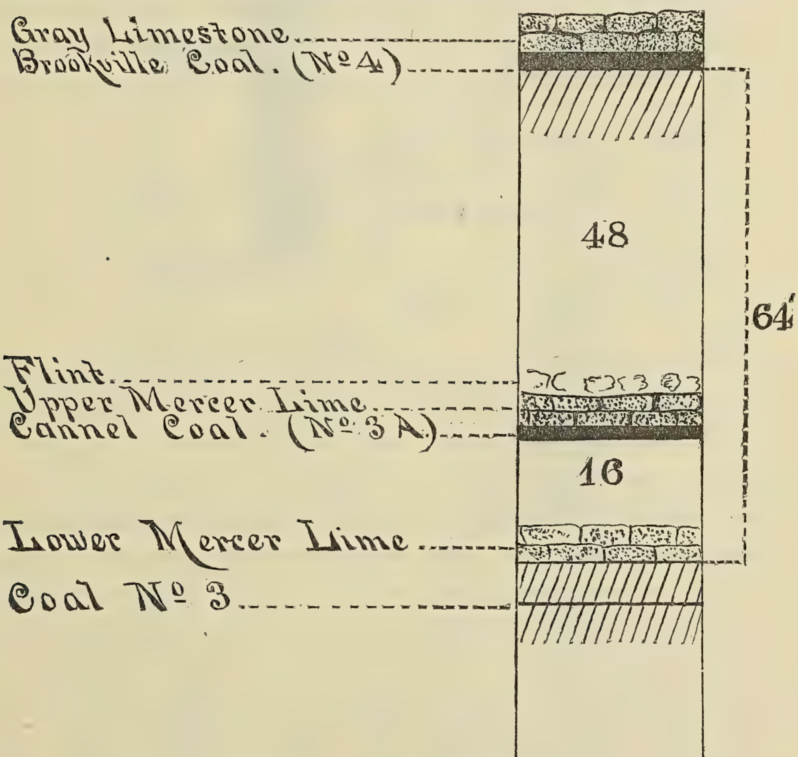


becomes harder again near the roof; it is rather pyritous, but as it will cost nothing to take it down, when the cannel is taken out, it may be a source of profit to the operator.

The same conditions prevail at the Lyman bank on the northern side of the ridge; the coal presents the same section and same general character, but is much more easy to mine. From this bank and that of Mr. Jas. Sharpless, near by, the sections were taken which led Prof. Hodge to pronounce it the Lower Mercer coal. From a consideration of the section at these two places only, his conclusion is a natural one. In this section the two upper elements are in their regular order and interval, but the remarkable substitution of the sands and shales in place of the Lower Mercer Horizon is immediately apparent. The

FIGURE III

SECTION ON JAS. SHARPLESS' FARM.



SCALE, 50 FT TO 1 IN

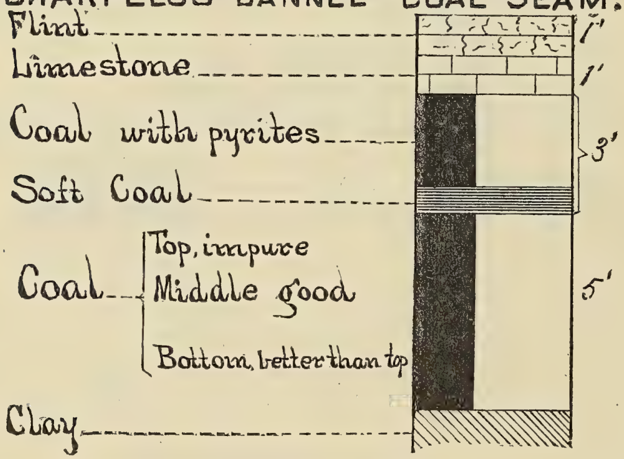
typical section of the whole cannel district and of a large band of territory extending nearly to the southern edge of the county is here given as it was measured on the lands of Jas. Sharpless, not more than ½ mile from the position of the former section.

This section is exemplified in nearly every ravine in the township, and along many of the public roads the elements crop out.

The structure of the Sharpless coal is much like that of the Mowrie Bank.

FIGURE IV

SHARPLESS' CANNEL COAL SEAM.



The soft coal over the cannel still affords every chance to the miner; the cannel is here in one of its best phases—it is highly conchoidal in its fracture, and breaks with no reference to its lines of bedding. The coal is divided into 3 grades; the middle is the best and the top coal the least desirable. In this top coal the most beautiful impressions of Stigmaria with lateral rootlets were seen; nearly every mine car contains what would be a prize in a geological museum. The composition of this coal differs in a marked degree from those cannels reported heretofore. This may be due to the selection of a sample, as it was the aim to get one which should fairly represent the run of the mine, including top, middle and bottom layers. The analytic methods also differ from those employed in the previous work of the survey.

Bedford Cannel Coal of Jas. Sharpless (Lord).

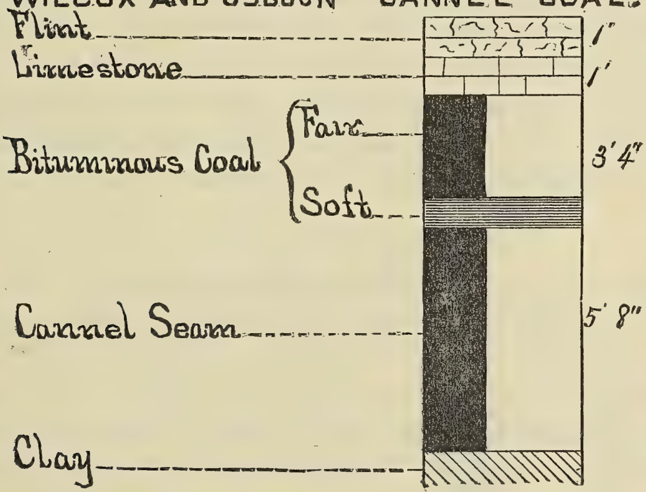
Moisture	2.35
Volatile hydrocarbons	47.05
Fixed carbon	37.00
Ash	13.60
Total	100.00
Sulphur	2.33

The high per cent. of ash is due partly to the mixing in of the top band, which is frequently rejected in mining.

The Sharpless bank is located on the northern edge of Bedford township; the largest part of the good coal lies due south of this point, extending in an elongated area nearly to Tunnel Hill. In this district, there are many more openings of the coal, but none as important as those already mentioned. Nearly 700 acres of the best of this land was bought by a railroad line, which was to tap this coal years ago. One mine, known as the Wilcox and Osbourne bank, is kept open in the center of this tract; from it the following section was obtained:

FIGURE V

WILCOX AND OSBUEN CANNEL COAL.



The owners of the tract will be fortunate if this section represents the whole of their property. At this same place the Middle Kittanning coal (No. 6) is opened in an outlier, one of the westernmost in the county.

We have now considered the area, structure, and developments of the Bedford cannel coal, the best deposit of its kind in Ohio, and one of the few developments of the Upper Mercer horizon, which assumes economic importance. Its thickness is seen from those places already described, to have considerable range; it runs from a mere streak to a maximum thickness of 9 feet at the Wilcox and Osbourne bank. In the banks now open in those areas called mineable, the cannel shows well, but in that larger part which of course is not accessible till mined, the thickness is unknown. Judging from the workings and exposures already made, it will not hold up to an average of 5 feet of cannel coal over the areas marked. Around the edges of this area it runs down to an insignificant size, in a very short distance. Further work could be done to advantage in making careful analyses of the different layers or grades, and also from averaged samples of all the different banks now open. Until this is done, the district will rest under more or less of an unfair representation, as *one* analysis on the *run* of *one* mine is surely not justice to the district. Further work would prove the character of the whole area, and might be the means of discovering some coal worthy of special adaptations.

One of the principal uses to which cannel coal is put, at present, is in enriching ordinary coal gas with those illuminants peculiar to the cannel. Its cleanliness and bright blaze make it also sought after for household use by those who can afford the luxury. In former years, it was extensively used as a source of the light oils which may be distilled from it. This industry had begun to assume large proportions when the discovery of petroleum put an end to it.

The Brookville Coal (*No.* 4).

In three townships in the western part of the county, this coal is developed to a small extent. They are Newcastle, Jefferson and Bedford.

In Newcastle township, there are 4 coal banks in this seam; they are the westernmost coal banks in the county. The coal underlies the gray limestone directly; this limestone is only a few feet beneath the hill tops on the western side of the township and about 2 miles beyond, runs out entirely. There is a remarkable shortening of the interval between the Lower Mercer and the Putnam Hill limestone at this point. The following section was obtained at the coal bank of Anthony Lavelle, close by Newcastle:

8.	Putnam Hill limestone, thin	135	feet.
7.	Brookville coal (No. 4), 28″ thick	132	"
6.	Coal streak (No. 3*a*?)	115	"
5.	Lower Mercer limestone	101	"
4.	" " Coal and clay (No. 3)	—	"
3.	Shales and shelly sandstone	98	"
2.	Heavy Massillon sandstone	50	"
1.	Sharon coal (No. 1)	0	"

This coal bank supplies coal to the south, west and north; its coal is of fair quality, and is preferred by many of the farmers to the cannel of Bedford township.

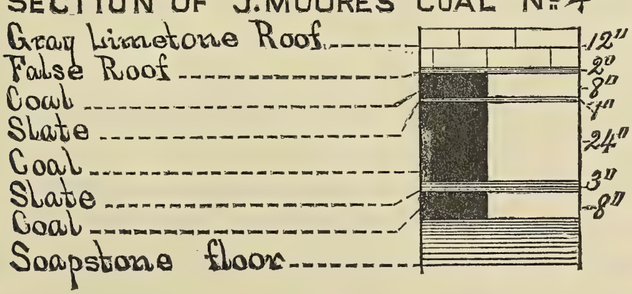
Calvin Staats and Samuel Severns also have banks in this coal about 2 miles south-east of Newcastle. Ransome Severns, on the eastern edge of the township, also mines this vein; it is here 32 to 36″ in thickness.

The Upper Mercer limestone is found 37 ft. below the coal, covering a mere streak of its own coal. The layer of flint, which belongs at this level, is here shown in strong force.

The coal assumes its best features in the next two townships, Jefferson and Bedford. It occurs in the same district as the cannel coal, and is more popular among farmers. In Jefferson township it appears in nearly every section and on nearly every farm. It is mined by John Moore, W. P. Wheeler, J. M. Creighton, and Wm. McNabb. None of these employ more than 5 men in the press of the winter's trade, and in summer all are idle. The coal is bright and handsome, mines easily by pick alone, and has an excellent roof. At John Moore's bank it shows the following section:

FIGURE VI

SECTION OF J. MOORES COAL No. 4



The two partings shown above always characterize the seam. Though it meets the demands of home consumption, it would probably show a high per cent. of ash on analysis.

In Bedford township, south of Jefferson, the coal still presents one of its most useful phases. Its development falls off from the center of the township southward, just about as No. 6 coal begins to be of some service. There are no banks of No. 4 coal east of Bedford township. On the farms of Elias Norris, Jacob Adams (2 banks), Ethan Wright, James Hardman, Elizabeth McCullah, and James H. Pigman, Bedford township, this coal is opened and worked. It runs from 3′ 3″ to 3′ 9″, and everywhere exhibits the same structure as seen in Fig. VI.

It is a fairly good coal, but yields considerable ash of a white color; it mines freely with use of powder. No analyses were made of it. It is everywhere found under a heavy bed of Gray limestone. The following section illustrates its position with reference to the Mercer group:

Section on the Lands of R. Barrett.

(Northern edge of Bedford Township).

7.	Gray limestone, thick	90	feet.
6.	Brookville coal (No. 4) 39″ thick	86	"
5.	Upper Mercer limestone, thin and flinty	60	"
4.	Cannel coal, 48″ thick (No. 3*a*)	56	"
3.	Lower Mercer limestone	25	"
2.	Coal streaks (No. 3)	13	"
1.	Ore nodules and coal streaks	0	"

Another typical development is found on the lands of Col. Pren Metham (N. E. ¼ of N. W. ¼ of Jefferson township):

7.	Putnam Hill limestone	100	feet.
6.	Brookville coal (No. 4) 36″	97	"
5.	Flint nodules	62	"
4.	Upper Mercer lime	56	"
3.	Cannel coal (No. 3*a*), thin	54	"
2.	Lower Mercer limestone, heavy	36	"
1.	Coal streaks (No. 3 ?)	0	"

Sections illustrating these relations can be repeated indefinitely. These developments of the Brookville coal, small and local as they are, are of a much more profitable character than this vein usually shows. Stark county is the only one which puts it to a wider use.

Lower Kittanning Coal (No. 5).

This horizon is an uncertain one in Coshocton county; in a large part of the district it does not appear at all; in only one township (Jackson) does it appear in workable dimensions. Along the hills fronting the Muskingum Valley, and about 1 mile south of Roscoe, the refuse of the old coal mines attracts the eye. On investigation it is found that debris has been accumulated on two different levels. The upper is seen to be the Middle Kittanning, and the Lower Kittanning is found 30 feet lower down. All the workings have long ago fallen in, and even the character of the vein is forgotten. Southward it disappears entirely, but along the Bedford road, westward from Roscoe, it is seen occasionally. In the S. W. corner of Jackson township a few exposures of it are seen. On the lands of J. M. Passmore the following section was measured:

6.	Middle Kittanning coal, 3′ 10″	85 feet.
5.	Nodular iron ore, at	75 "
4.	Calcareous sandrock, at	60 "
3.	Lower Kittanning coal, 4′ 0″, at	54 "
2.	Gray limestone	6 "
1.	Brookville coal (thin)	0 "

The lower coal is not worked; it is covered by a peculiar deposit of calcareous sandrock of local character. On the lands of Robert Crouch, Sec. 16, Jackson township, both coals are opened, but the lower is not worked to any great extent. It is inferior to the Middle Kittanning coal.

The Middle Kittanning Coal (No. 6.)

This seam, which is quite widely known as the Coshocton coal, is the main economic feature in the geology of the county. It is the only coal in the county which finds its way to outside markets, and besides this it supplies the bulk of the home demand.

The line of western outcrop of the coal and the areas occupied by it are shown on the map that accompanies this report; at Spring Mountain, Monroe township, its westernmost exposure appears near the top of the hill on which the town is situated, but it makes but a point on the map. No further workings are found to the eastward until about two miles from Helmick, Clark township. On the land of John Moore, one mile east of Mohawk, an outlier of No. 6 coal is found in the very

summit of the highest ground; another is found about ½ mile west of the town of Bedford. The line of the outcrop of the coal runs nearly north and south and about 4 miles to the eastward of this line of outliers. Passing into Washington township the line swerves to the east, and the last opening in No. 6 coal is found about 3 miles west of Adams's Mills just inside the county line.

No. 6 attains position as a mineable coal very soon after its first outcrop appears. Beginning in Clark township, where it enters the county from the north, its development will be noticed in each successive township southward.

Clark Township.—The whole supply of fuel in this township is derived from the No. 6 coal. The mines are all situated in a group on the southern edge of the township. The hilly ground to the northward holds the veins, but in unpromising condition. The first good coal is found just south of Killbuck Creek, at Helmick. It is opened on the farms of Wm. Darr, Nich. J. Mullett, Joel Glover, Thomas Elliott and Samuel Felton. The coal is nearly uniform in appearance and quality; it is quite strongly coking; burns with the production of much tarry matter and the evolution of a good deal of gas, and makes a hot fire. It is high in sulphur and destructive to the linings of stoves. Its ash is a strong purple red color. Its thickness ranges from 30″ to 42″, occurring in two benches, separated by 2″ or 3″ of clay or soft slate.

On the lands of Samuel Felton, Section 17, the following section was obtained:

6.	Middle Kittanning coal (No. 6), 32″	128.′
5.	Probable level of Putnam Hill limestone	70.′
4.	Upper Mercer limestone	38.′
3.	" " Coal (No. 3*a*)	36.′
2.	Lower Mercer limestone (Zoar)	10″
1.	" " Coal (No. 3)	0.′
	Total	128.

Other sections are found in this vicinity, which show the Putnam Hill limestone at its normal level above the Lower Mercer, though it was concealed in this case.

Bethlehem Township lies to the south of Clark and east of Jefferson. Across its southern and western borders the valleys of Killbuck and the Walhonding river have cut out all possibility of coals. No

coal is worked in the township, except that of J. C. Endsley, on the northern edge, and just over the line from the workings in Clark township, already described. The same features characterize the seam here as at those banks just north of it; it is a coking, red-ash coal, high in sulphur, and making a very hot fire. It is called "rich" and "fat" by the people of that country. It is bright and handsome, rather tender, and quite high in sulphur. At this bank it is 3′ 10″ high, on the average, and occasionally 4′ 2″, with one clay band near the bottom.

A section measured at this locality presents the following elements:

6.	Lower Freeport coal? (30″)	178.′
5.	Middle Kittanning coal (No. 6) (42″)	108.′
4.	Putnam Hill limestone	76.′
3.	Brookville Coal (No. 4) (18″)	74.′6″
2.	Lower Mercer limestone	1.′
1.	Lower Mercer coal (No. 3)	0.′
	Total	178.

The special feature to be seen in this section is the remarkable shortening of the interval between Nos. 4 and 6 coals.

Jefferson Township, lying just west of Bethlehem, has already been mentioned as containing an outlier of the Middle Kittanning Coal. No banks are opened in it.

In *Bedford Township,* the coal begins to assume economic value. Besides one bank, questionably No. 6, all workings are found in the south-eastern ¼ of the township. There are 4 banks now open, viz.: Daniel McCurdy, Sec. 19; Wm. Sproul, Sec. 19; Wm. Parrish, Sec. 19; and Perry Sisley, Sec. 22. Besides these, several other farmers have openings, but little used. The coal is soft and easily dug; no powder is used and often a pick alone suffices. Under good cover it is black and cubical, though quite red on the outcrop, and it is quite cementing in character. It runs from 36″ to 42″ in thickness, and carries the clay band which characterizes the seam throughout the county.

In *Washington Township,* the No. 6 coal barely enters. No openings have been made. This completes the line of townships in which the westernmost workings and exposures are found. It has been noticed that the distance between the line of first exposures, or out-

liers, and the line of workable coal is very short; about 4 miles is the usual distance. The coal in these townships exists in too small areas to become a basis of large mining operations. It is too near the outcrop, and consequently too poor in appearance to bear competition in railroad markets, but it will serve an important purpose in supplying the home demands of the population for years to come.

In the second tier of townships, just east of those described, this seam possesses quite unequal values. In several of the townships it is at its best for Coshocton county, while in others it has but little worth, as will be shown. The townships of this second tier are Mill Creek, Keene, Jackson and Virginia.

Mill Creek.—The coal developments of this township are limited. The lands on the north are very high, and rugged, and the coal does not seem to be of any value on them. On the south, the coal is worked in a small way, but the abundance of wood, for fuel, makes the use of coal less general.

Keene Township.—The Middle Kittanning coal is worked in this township on only 2 farms, though nearly all the ground holds the seam. The proximity ot the constant and cheap supply of the mines around Coshocton discourages the opening of the usual number of country coal banks. At the mines of Messrs. Boyd and Wolf, near the center of the township, the coal is much like the true Coshocton coal, though a little diminished in thickness.

Jackson Township.—The whole of this township was originally underlain with the Middle Kittanning seam, and it has managed to save 80 to 90 per cent. of the seam from the accidents of erosion. In the north-western corner of the township, the seam appears in the hill tops. In the south-eastern corner, in the direction of the dip, it has fallen to an accessible level above rail or canal. The coal workings thus far are confined mainly to 2 districts. The north-western corner of the township, being so near the Bedford mines, obtains its coal mainly from this source. The eastern edge gets its coal partly from Coshocton, and partly from mines to the southward. In the center and south-western parts of the township a number of banks are kept running. Prominent among these is that of Wm. Parks, Esq., in the extreme south-western corner of the township. The Parks coal is 44 inches thick and of good quality. The following section was obtained at his mine:

9.	Middle Kittanning coal (44″ thick)	140′
8.	Calcareous sandrock, peculiar to that locality	114
7.	Lower Kittanning coal (48″), poor grade	110
6.	Putnam Hill limestone	61
5.	Brookville coal (No. 4)	60
4.	Upper Mercer limestone, flinty	21′8″
3.	" coal (No. 3*a*), streak	——
2.	Lower Mercer limestone, heavy	10″
1.	" coal (No. 3)	0
		140′

This section is one of the best that was measured in the county. In it appear all the regular elements at their normal levels, together with those which are not constant in their exposures, viz., the Upper Mercer horizon and that of the Lower Kittanning.

No. 6 coal here is an excellent house coal, but is quite tender, which would be unfavorable to its shipping qualities. Near the Parks bank, in Sec. 25, is found the mine of J. M. Passmore. It is No. 6 coal, 46″ thick, with a strong red-ash, a little sulphury, but on the whole very justly popular in the neighborhood. This bank affords work for 1 or 2 diggers all the time, and as many as 5 or 6 find work in winter. In this same locality are the banks of John Dicky, Sec. 25; J. Darr, Sec. 24; Owen Marshall, Sec. 16; Robert Crouch, Sec. 16; Ira Bell, Sec. 16; McCoy's Bank, Sec. 17, and Sam'l Kirker, Sec. 17. In these openings the coal ranges from 46″ at one of the southern exposures to 36″ on the northern edge of the group. The coal is rich and coking, of a bright, waxy luster, with a strong cubical cleavage. It is tender and soft, being mined wholly by pick. Though very highly prized for domestic purposes where it is known, its softness will place it at some disadvantage in the general markets. The shaly parting comes about $\frac{1}{3}$ of its height from the floor. The "cutting" is done either on the parting or below it. The eastern side of the township has also quite a list of coal openings from which to draw. Two miles from Roscoe, on the Coshocton and Bedford road, is the bank of Geo. Randle, which is worked in the winter time quite extensively as a neighborhood bank. The coal is drawn from the valley below to the top of the ridge on which the road is built by means of a horse-power drum and incline. Southward from Randle's and in the second tier of hills parallel to the Tuscarawas river, are located the banks of Jos. Stubbs, Margaret Crown and others, of small value. On the hills fronting the river, the coal is opened at short intervals for

4 or 5 miles down from Roscoe. One-half mile south of Roscoe are the banks of Wm G. Moffat. At this place the Lower Kittanning coal is seen.

Mr. Moffat has two banks, both of which are reached by inclines, the coal being run down into a tipple for wagons or over the canal. The coal is of good quality; it presents this section:

8.	Slate roof	——	
7.	False roof	10″	
6.	Top coal	34″	48″ coal.
5.	Pyrite	1″	
4.	Bottom coal	12″	
2.	Clay	2′	
1.	Hard boulders	0	

The thickness ranges from 3′ 10″ to 4′ 2″; the new bank has been opened with great care; is well timbered and drained; considerable land is accessible through this opening, and it will probably be active for some years to come. Another important opening in this township is that known as Prosser's Bank. It is situated in the south-east corner of the township, in lot No. 1. It is now owned by Jones, Uffner and Jackson, of Coshocton. The mine is distant two miles from the canal, but it is connected with it by an iron track tramway. It has done in past years a large business on the canal, but it has fallen into decay, and will require considerable outlay to put it into good working order again. It is estimated that 10 or 15 acres of coal have been mined out here. The coal is said to average 4 feet in thickness, but access to the rooms was not practicable when the mine was visited. In the entry, near the bank's mouth, the coal is 4 feet strong, and it is also 4 feet 2 inches thick in an entry on the north-west side of the hill, on the Lillibridge farm.

The largest workings of Jackson township remain to be named. The Coalport Coal Company has mined out 140 acres in a rectangular block, 80 rods wide, on the east side of Section 21, and the Summit Coal Company has mined out 10 to 15 acres to the west of the Coalport workings, but connecting directly with them.

In the Coalport mine, the coal was found an unbroken body, nowhere less than 3 feet 2 inches in thickness, and probably averaging 3 feet 10 inches. The seam was somewhat reduced, however, to the northward, not showing more than 3 feet 6 inches at the end of the entry. In the Summit mine a thickness of 4 feet is claimed for some

rooms. The roof is better than the floor. A heavy bed of white, plastic clay underlies the coal, and has a tendency to heave, unless the water is taken good care of. The roof is shale and has ordinary strength, but it "cuts," under the action of the air, when left for a number of years. In such cases a good deal of timbering is necessary, if danger is to be avoided.

The coal produced by the Coalport mine was of the usual type of the Coshocton seam, and always took a good place in market. The mine was made to yield in its later years nearly 4,000 tons, "run of mine," to the acre. Good mining ought to gain more than this from a seam of this thickness.

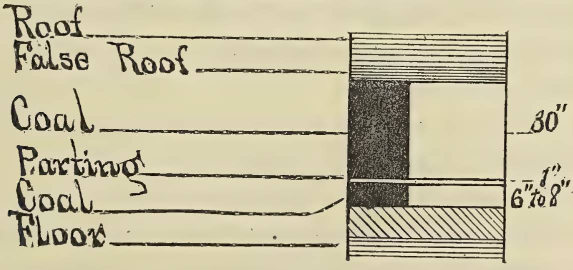
A large body of coal of this same character occupies Sections 11, 12, 19, 20, 21, 22, and lots 1, 2, 3, 4, 5, 6 of this township. Much of this would find an easier outlet by the Coalport route than by any other.

In conclusion, it may be said that there is in Jackson township a larger area of the Coshocton coal than in any other township of the county. The condition of the seam also is as favorable here as in any other part of the county.

Virginia Township probably ranks next to Jackson in its area of this coal seam among the townships of the county. The largest and most valuable area is included between the little Wakatomika and the Tuscarawas valleys. There are more than 4,000 acres of coal land in this body. The mineable deposits beginning in southern Jackson extend through this township into Muskingum county below. The character of the vein is illustrated by this section, measured on the lands of John Vickers, near Adams's Mills :

FIGURE VII

VICKERS COAL № 6

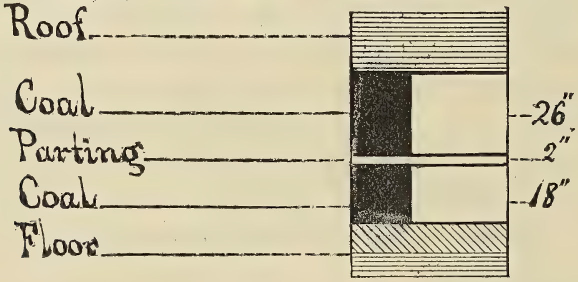


This section holds good in all the exposures to the north and westward. There are many country banks in this township. Those

most prominent are John Vickers, Race Bland, John Cox, Geo. Cox, of Adams's Mills; John Barclay, of Conesville; Abner McCoy, of Willow Brook; Wm. Huffman, Wm. McDonald, John Cornell, Sam'l Perkins, Thomas Darr, Asa Meek, and Geo. Wright, of Moscow.

The coal is thinner and of a poorer grade at Moscow than in the other districts; it presented the following section in the bank of Wm. McDonald:

FIGURE VIII
McDONALDS COAL



Going eastward, the coal thickens up to 4 feet at Abner McCoy's bank, near Willow Brook, and about 3 miles west of the Tuscarawas Valley. About one mile to the south-east of this mine are the new mines of David Davis, and 2 miles to the north-east are the Old Coalport mines. So the thickness of the coal at this point is of value in determining the extent of the development of the 4-ft. coal on which these large mines are established.

There is but one railroad shipping bank in the township, viz., the Davis mines already named. The Davis mines, owned by Davis Davis, of Conesville, are at present the most active in the county. They lie at the head of a small water-course, about 2 miles north of the Pan Handle Railroad, at Conesville, being located in the north-west corner of Section 11. The tipple and shoots are arranged to deliver coal to the canal or railroad at will.

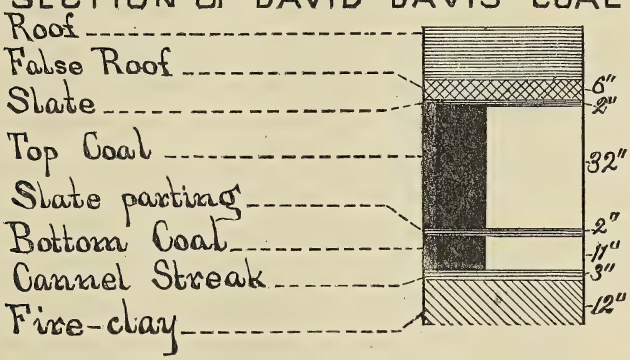
The tramway to the mines is of T-rail, but it is soon to be replaced by a railroad track. There are two banks now run by Mr. Davis; the old mine or No. 1 employs now only about 15 men, and the new mine 45, counting in miners and daymen as well, making about 60 employes. A large part of the coal taken out is sold to the Pan Handle Railroad. The road takes the run of the mine, slack and all, as the coal is so strongly coking, that it agglomerates when put into a hot fire. When

the coal is sold to outside parties it is screened over 1¼-inch screens, as is customary in the valley. The coal stands screening but poorly, and the value of its slack is such that screening might well be dispensed with. The result of a series of experiments at this mine shows that about 40 per cent. of the contents of the bank cars will run through the large screen before it is on the cars ready to ship. The mining price is about 55c. a ton on run of mine, which corresponds to about 90c. a ton on screened coal.

The structure of the coal is shown in the following section from Davis's mine, No. 1:

FIGURE IX

SECTION OF DAVID DAVIS COAL



The coal at mine No. 5 is exactly the same, but without the cannel streak at the bottom. The coal at both banks is of the variety called peacock. Like the Coshocton coal generally, it is best suited for household purposes, though also an excellent steam coal.

Its composition, obtained from a careful sampling of the seam, is as follows:

Coshocton Coal from the Davis Mine (Lord.)

Moisture	4.61
Volatile hydro carbons	44.73
Fixed carbon	47.83
Ash	2.83
Total	100.00
Sulphur	2.28

From its analysis we would infer just such qualities as the coal is noted for; it is low in ash, rather high in tarry matters, and cokes quite strongly. The ash is of a characteristic purple-red color, and

burns down to a fine powder, with very small tendency to form clinker.

Franklin Township, lying just east of Virginia, has in old times furnished some coal to the shipping trade. The most extensive workings were at Rock Run, on the northern edge of the township. Considerable territory has been worked out at this point, and the old mines were abandoned. Recently, another opening has been made by Messrs. McNeal and Harris; about 20 men are employed, and the coal is shipped on the Pan Handle Railway. The broad valley of the Muskingum has cut out the coal from a considerable part of the township. A few small country banks are open at Frew's Mills.

Tuscarawas Township, just north of Franklin and east of Jackson, and containing the village of Coshocton, has furnished more coal to the outside markets than all the rest of the county. In it were located the old Pen Twyn mines, Shoemaker's bank, Beech Hollow mines and the Union mines. Beside these large workings, now deserted, the Home mines and the Morgan Run Coal Co.'s Works are still in operation.

The Union bank, 2 miles south of Coshocton and on the first tier of hills fronting the river, has been last abandoned. The coal is very badly troubled in this bank; its height runs from 3′ 7″ to 5′ 9″, with 4′ 10″, on an average of 15 measurements. A series of rolls or "horsebacks" starting, like curved spokes of a wheel from a common center, were continually cut by the entries and rooms and made a great deal of expensive dead-work. As the working progressed, these horsebacks began to be understood, and were finally so worked as to cause a minimum of expense. Soon afterwards, the entry-men drove into what appeared to be a true "fault," or slip, in the strata. The coal was cut off square and sharp, while the rock beyond was an intensely hard fine-grained sandrock, which properly belonged 40 ft. or so above that level. Down the sides of the great slip, the triturated fragments of coal had been carried for a number of yards. This fault was found to be general, and to extend in a long arc between their workings and the body of coal beyond it. The company spent much money and trouble in trying to pierce it, but gave it up finally and abandoned the mine; beyond, lay 200 acres of valuable coal, but it cannot be reached, except by piercing the fault.

The work was prosecuted day and night for a long time, but without success; the rock was very hard and could not be attacked to good

effect without compressed-air drills. The quality of the coal here is not so good as that of Virginia and Jackson, but is still very fair.

The following analysis shows its composition:

Coshocton Coal—Union Mine—(Lord).

Water	4.41
Volatile hydro-carbons	43.98
Fixed carbon	46.38
Ash	5.73
Total	100.00
Sulphur	3.99

The switch, shoots, and tipple were the finest of any coal works in the county.

The Beech Hollow mines, Pen Twyn, and Shoemaker's, are all old workings, and have all furnished large amounts of coal for the general market.

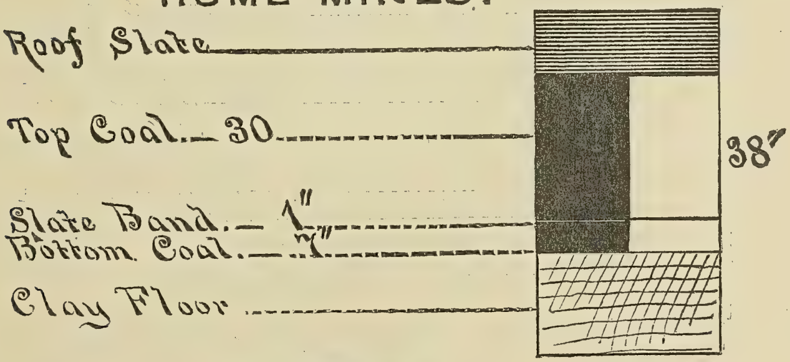
The Home mines are the only active mines in the township at present.

The coal at this place is thinner than in any of the southern developments; the average of a number of measurements was 3′ 2″, with a maximum of 3′ 7″ and a minimum of 3′ 0″.

It presents the following typical section:

FIGURE X

STRUCTURE OF COSHOCTON COAL HOME MINES.



SCALE, 5 FT. TO 1 IN.

The coal is found to have a local undulation, or to lie in alternate elevations and depressions; from the center of one of these elevations to the valley corresponding, the distance ranges between 150 and 300 yards; the vertical rise and fall in that distance is about 10 ft. The entries are driven at a definite grade to secure easy hauling and drainage; this makes a good deal of stripping down roof and shooting up floor necessary, and hence a good deal of unusual expense for dead work.

The quality of the coal is very good; it is popular in a number of western markets. Its composition is shown in this analysis:

Coshocton Coal—Home Mine—(Lord).

Water	5.07
Volatile bituminous matter	42.07
Fixed carbon	48.40
Ash	4.46
Total	100.00
Sulphur	2.91

The diminution in thickness from the Union mines is attended with a slight improvement in the quality. These mines ship nearly all their coal to distant markets; none is now used by the railroad. The mine employs about 55 or 60 men, about 20 per cent. of whom are day-hands. The mining is done without powder, pick and wedge giving the best results. The only other mining enterprise now in the county is the Morgan Run Coal Co.'s Works. The company belongs in Cleveland, and it is intended to get the Coshocton coal into that market, direct by the Connotton Valley narrow-gauge railway. The mines are just ready for shipping, and the entries and openings are being pushed as rapidly as possible. The equipment of the mine is excellent, leaving nothing to be desired for efficient and economical work. The entry is made upon the dip, and to escape from trouble as to drainage, its mouth is located about 17 feet below the coal. The mine is about 160 feet above the level of the railroad track in the Tuscarawas Valley, 3 miles distant. It is reached by a narrow-gauge switch. It is expected that loaded cars will run down to the main line by gravity.

The mines are worked on the double entry system; the coal is 36″ thick, and remarkably steady, so far as the entries have yet advanced. Its quality seems excellent, and it works very kindly. Thicker coal is

hoped for as the entries are extended. The coal is iridescent (peacock coal), quite tender, and apparently, in all respects, a typical example of the Coshocton coal. The company is prepared to send a steady and large supply into the city of Cleveland, where it will undoubtedly establish a place for itself as the Coshocton coal has already done in all of the markets that it reaches.

Around the town of Coshocton are several banks which supply the town with coal. Prominent among these are the mines of

J. Robson, employing		20 men.
Wm. Hay,	"	15 "
Wm. S. Hall	"	10 "

In Lafayette and Oxford townships, the areas of the Kittanning horizon are small on account of the extensive erosion of the Tuscarawas river and its chief tributaries. There are no important mines in these townships, and but few farmers' banks, in comparison with other sections of the county.

In Linton township, the coal seam that we are following falls below drainage finally. It is, however, mined in a few localities. Near Jacobsport, quite a cluster of country banks is gathered, all of them in the Middle Kittanning seam, which does not exceed three feet in thickness.

In the townships north of the river, there is but a feeble mining interest, and but little work was therefore done here by the Survey. In Crawford, but very little coal is mined. In White Eyes, an extensive area is occupied by the seam, but little is known as to its condition here, and much the same state of things is true in Adams township.

CHAPTER XV.

THE COAL SEAMS OF THE LOWER COAL MEASURES OF OHIO—Continued.

Mines of Muskingum and of Licking Counties, and of the Northern Half of Perry County.

By Edward Orton.

On map No. 5, accompanying the present volume, and which covers Muskingum and parts of Licking and Perry counties, the boundary of the coal measures is copied from Newberry's geological map, and, in addition to this, the areas of the Kittanning coals lying above their final descent below drainage are represented. As these coals are by far the most important sources of fuel supply to the district and in a large part of it the sole supply, no question will be raised as to the propriety of selecting them for special delineation. The boundaries were not run with the accuracy that would be demanded in buying or selling the coal lands of a farm or section, but they will be found a safe guide for all general work, such as the laying out of railroad branches and the locations of mines requiring an expensive plant. From the map it can be seen where the large bodies of the coals of this horizon are due, and where they can be attacked at best advantage.

In addition to the Kittanning horizon in Muskingum and Perry, the Ferriferous horizon of Licking county, which is practically identical with the former, is represented in the well-known Flint Ridge, alike interesting geologically and archæologically.

Coal Mines of Muskingum County.

Muskingum county, as pointed out by Andrews, has the greatest vertical scale of any Coal Measure county in Ohio. Its lowest rocks are in the Logan division of the Waverly group (Sub-Carboniferous), while

in the south-eastern townships the strata extend to and include three or four coal seams above the horizon of the Pittsburgh coal.

The geology of the county has been treated at some length in the report of Andrews, Vol. I, Chapter XII, and also in Stevenson's report in Volume III, Chapter LXIII, and to these reports the reader is referred for the details of stratification and the facts of the general structure of the county.

The Lower Coal Measures, in particular, are shown in their whole extent and in unusually short and compact sections. The sections are, however, somewhat aborted. From the valley of Jonathan's Creek, near Uniontown, in which the Newtonville limestone of Chester limestone age is found in strong development, we can ascend in a single hill to the level of the Lower Freeport coal, at least, and possibly to the Upper Freeport horizon, but in the section only two of the coal seams that are due are found of economic value, and several are altogether wanting. There is no trace of the Sharon or Quakertown coals, Nos. 1 and 2, and none of the Clarion coals. These sections are shown on page 99 of the present volume.

There are but three seams of the Lower Coal Measures that attain any considerable importance in Muskingum county, viz.:

Upper Freeport coal, known as			No.	7.
Middle Kittanning coal	"		"	6.
Lower	"	"	"	5.

In addition to these seams, which are mined in the large way, small coal banks are opened in the coal seam below the Putnam Hill limestone, in the seams under the two Mercer limestones, and especially in the lower of the two. Stevenson describes banks also in the lower horizons of the Quakertown and Sharon coals, Nos. 1 and 2, but there is very little value in any or in all of this list.

In Hopewell township, along the line of the National road, there are several small mines opened in the Lower Mercer coal (Coal No. 3), which have yielded fuel to the immediate neighborhood for a number of years. This coal has been generally referred to the Putnam Hill limestone horizon, but the reference originated in the error that prevailed for some years as to the place of this limestone, it having been confounded with the Lower Mercer limestone. The Hopewell coal is probably the Lower Mercer coal (Coal No. 3). It is mined by James Dick, Esq., and has been mined in years past on the Porter farms, and also upon

others in the neighborhood. In the adjoining township of Hopewell, in Licking county, is the celebrated Flint Ridge. The flint belongs to the horizon of the Ferriferous limestone, but at the northern base of the ridge is the finest development of the Lower Mercer coal in this portion of the State. It is the well-known Flint Ridge cannel coal. The cannel has been found in full thickness at but a single locality. A brief account of this deposit will follow on a later page of the chapter. It is upon the south-eastern side of the Ridge that the mines of Muskingum county, already referred to, are situated. The coal here is ordinary bituminous coal, divided by a number of partings, and consequently a dirty seam, but it has good thickness, and may fairly be counted as supply that will at some time become available. There would seem reason to believe in considerable area of this coal in these two townships, and possibly in adjoining ones. There is not likely to be any large demand for it aside from the accessible portions of the cannel coal, under the conditions that now prevail, as it cannot compete with the better seams around it so long as they are produced so cheaply.

The other seams that are named in this subsidiary list are insignificant as sources of fuel. Their main interest is in their occurrence as geological elements.

A small mine has lately been opened in the coal below the Putnam Hill limestone (the Brookville coal, Coal No. 4; Coal No. 3*b*) within the city limits of Zanesville, but the thickness of the seam is small, and it cannot support any continuous or extensive operations.

It is not necessary to dwell further upon these thin and inconstant coals. Their places can be determined by the general section given on pages 96, and by the particular sections given on page 99.

Of the three seams already named as the really important sources of fuel, the Middle Kittanning, or Coal No. 6, is by far the steadiest. Both of the others, viz., the Lower Kittanning, No. 5, and the Upper Freeport, No. 7, are inconstant and irregular to a high degree, and yet each of them furnishes a good basis for mining in numerous localities in the county. Each of these will be briefly characterized.

The Lower Kittanning coal is a bright, well-faced coal, carrying about 50 per cent. of fixed carbon, about 40 per cent. of volatile combustible matter, and about 4 to 5 per cent of ash. Though quite high in sulphur, averaging over 2 per cent., its ash is generally white. It mines small, and the seam yields considerable dirt in many localities.

It holds the fire well, and is counted a strong and serviceable coal, but it does not ignite as easily as the seam above it.

The Middle Kittanning seam (No. 6) is also a bright, cubical coal, mining in small or medium size blocks. It kindles easily, burns with a long flame, and is in especially good repute as a steam coal, and is also highly valued as a grate coal. In Zanesville it is also used as a gas coal. It contains always less than 50 per cent. of fixed carbon, and always more than 40 per cent. of volatile matter. It is low in ash, averaging less than 4 per cent., the color of the ash being characteristically purple. Of sulphur, it contains more than 2 per cent. In other words, the seam still holds the characteristics that have marked it from Stark county southwards. Through Tuscarawas, Holmes and Coshocton, it is constant in maintaining the features given above.

The Upper Freeport seam also holds the general characteristics that have been found to mark it, in its great centers of production already described, viz., Salineville, Sherrodsville and Cambridge. It contains an average of 53 per cent. of fixed carbon, and always less than 38 per cent. of volatile matter, with a single interesting exception to be hereafter noted. Its ash is moderate in amount, and is seldom or never red in color. It contains less sulphur than the Kittanning coals. It mines fairly large, but is a weak coal, breaking up easily under handling. It is well esteemed for all ordinary uses throughout those portions of the county where it is mined, but it is everywhere divided by shale partings that cause it to be a dirty coal, unless well-screened.

The Kittanning Coals, Nos. 5 and 6.

The two Kittanning coals are but 16 to 30 feet apart, and they therefore hold about the same areas where both are developed.

The lower coal, as will have been already learned from previous chapters, is weak and uncertain throughout Holmes and Coshocton counties. Its horizon is often clearly enough shown, but few or no mines are reported in it to the west and south of Tuscarawas county. This same state of facts continues throughout the northern half of Muskingum county. It is not until we reach the neighborhood of Zanesville that we find it again becoming a basis for profitable mining. In the 6th ward of Zanesville, and in sub-sections 1, 2, 3, 4 and 16, Washington township, it has long been worked. It is known as the "Four-

foot seam," but it reaches a thickness of 4 feet 10 inches for its maximum, and carries $4\frac{1}{2}$ feet through considerable territory. The basin originally included about 800 acres above drainage, as nearly as it can be judged from the exterior boundaries. The coal thins down abruptly on the northern margin of the basin. It is not found thick enough for mining north of the Baltimore and Ohio Railway, and it does not crop out in the river bluffs. The valley of Mill Run affords the best access to the basin, and most of the mining in the seam has been carried on here. South of this valley the coal is cut out abruptly by a heavy sandstone.

South of Zanesville, in the river hills, the Lower Kittanning coal nowhere appears, though its companion seam is everywhere present and worked. At the horizon where the lower coal is due, a buff limestone bearing an ore and also a bed of fire-clay is often found. This series is also well shown on Putnam Hill, opposite Zanesville; the limestone is here 27 feet below the Middle Kittanning, or No. 6 coal. The limestone is fossiliferous, and contains well-preserved forms, among which large bivalve shells are especially noticeable. Reference has already been made to it on page 97, and the suggestions there offered as to its place in the series are the best that present knowledge warrants.

The coal of this basin, so far as it has been worked, is a two or three-benched coal. The main parting, and sometimes the only one, is a sulphurous band, two or three inches thick, and 18 or 20 inches from the top of the seam. Nodules of pyrites are often found near this parting also. At a little less than a foot from the bottom, a "bearing-in" slate is often found. The seam is mined by undercutting and blasting, one pound of powder being expected to bring down 20 tons of properly prepared coal. Rooms are worked 15 feet wide. There is often found a thin band of slaty coal at the top of the seam, which is taken down and sent out with the balance. The irregularities in the seam occur mainly in the bottom.

The coal is sold in Zanesville exclusively, all of the mines depending on carts and wagons for the distribution of their products. The seam is applied to all ordinary uses. It is preferred by many for household use to the coal of the upper seam, as it holds its fire longer. It is used quite largely by the Ohio Iron Company as a milling fuel, and it is also used as a steam coal to some extent. It is, as a rule, sold at a lower price than the upper coal.

Its composition, as sampled from Harper's bank for the survey by Mr. E. C. Downerd, and analyzed by Professor Lord, is as follows:

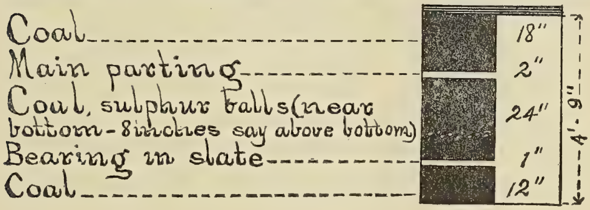
Lower Kittanning Coal, No. 5, Zanesville.

Moisture	4.93
Volatile combustible matter	39.72
Fixed carbon	49.96
Ash	5.39
Total	100.00
Sulphur	3.45

The structure of the seam at this same bank is indicated in the following figure:

FIGURE LXXIII

STRUCTURE OF LOWER KITTANNING COAL (Nº 5) HARPER'S MINE ZANESVILLE



Neither the composition nor the structure given above would apply to every portion of the basin, but the figures probably do no injustice to the seam taken as a whole.

A considerable area has already been worked out, but just how much it is impossible to say. Small mines worked irregularly and often with sole reference to immediate returns, have been driven under the hills at many points, and the outside coal is pretty largely cut away. To gain the remainder, it will soon be necessary to sink shafts into the unbroken coal. As to the extension of the seam to the south-eastward, under drainage, no facts are at hand, but the abrupt boundaries upon the open sides of the basin rather lead us to expect similar boundaries in the portions of the basin that are under cover.

There is but one other district of the county in which this seam is extensively mined. In Newton township, in the south-western corner of the county, a valuable field of the Lower Kittanning coal has long been worked. It is here known as the lower Del Carbo coal. It connects directly with the Perry county coals of Harrison and Clayton townships, and will be best described in connection with them.

The Middle Kittanning Coal.

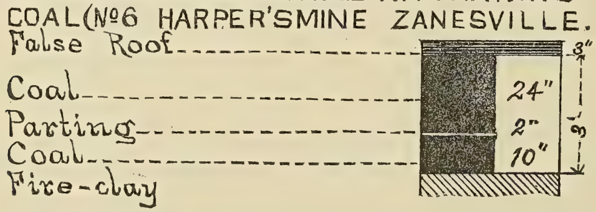
The Middle Kittanning seam, known as the Upper Zanesville coal, or No. 6, has already been shown to be the most remarkable seam of the Lower Measures of Ohio in steadiness and persistency. These characteristics it retains in full measure in Muskingum county. It enters the county from the northward, extending from the Coshocton line to which its development has already been traced in the preceding chapter, in a sheet, the continuity of which is scarcely broken, except by the accidents of the great system of erosion which is still in progress.

It is due above the drainage levels in the following townships of the county, viz., Monroe, Adams, Madison, Cass, Muskingum, Falls, Washington, Wayne, Springfield, Newton, Clay, Brush Creek and Harrison, and also in Zanesville corporation. In all of them the seam is mined, and in several of them to quite a large extent. It is mined for the general market in railroad or river mines, in Washington, Newton, Clay, and Brush Creek townships, and, as was stated under the previous head, the very large local supply of Zanesville is mainly furnished by carts and wagons running from mines contained within the city limits.

The seam falls short of 3 feet in parts of the field, and it nowhere yields fully 4 feet of coal, but it holds, with surprising steadiness, a measure ranging from 30 to 42 inches of coal. Its structure, too, is maintained with great regularity over large areas. The structure of the coal in the Harper mine of Mill Creek Valley, sixth ward of Zanesville, is shown in the following figure:

FIGURE LXXIV

STRUCTURE OF MIDDLE KITTANNING COAL (No. 6 HARPER'S MINE ZANESVILLE.



The same figure would answer without essential change for all the northern and central townships. The lower bench expands or contracts a little, but the upper is very uniform. To the southward, however, a change occurs. In Newton and Clay there is a considerable thickening of the lower bench, accompanied by a reduction of the upper bench.

The false roof is also increased, or there is added to it a distinct seam of what is called bone coal, a bed 6 to 12 inches in thickness and a true coal, but too high in ash to be marketable. Also in following the seam southward through the deep valley of the Muskingum until it finally sinks below drainage, we find upon the extreme boundary its measures reduced and its quality impaired.

The mines in this seam, in Monroe, Adams, Madison, Cass, Muskingum, Falls and Springfield are mainly country banks, each one giving place to two or three miners at most for the fall and winter months. The workings are generally characterized by lack of skill, and thus want of true economy. It is outcrop coal that is chiefly mined, because it is more easily reached. There is, however, a large acreage of the seam that awaits development in the townships named. There is the least amount in Cass, Muskingum, Falls and Springfield, the coal here rising high in the hills to its western outcrop. The range in thickness throughout this entire region is between 3 and 3½ feet. The seam no doubt exists to the eastward of the northern townships named. In Perry and Salem, particularly, it is due within moderate distance below the main valleys, and there is every reason to expect that it will be found of fair mining volume when properly tested.

In Washington township, a considerable and at some times a large production has been maintained for many years. The coal has found market by the Cincinnati and Muskingum Valley, and the Baltimore and Ohio railroads, upon which the mines are situated. The front hills are already mainly exhausted, but a large acreage is still available and tributary to these lines of outlet.

Coal Dale, on the Baltimore and Ohio Road, has been a chief center of production, and work is still going forward at this point and in the immediate vicinity. Horton, Matthews and Taylor are now mining on a larger scale than any others in this neighborhood. Their coal in one mine is at present running below the normal measure of the seam. It is the bottom bench, as usual, that suffers. This is here reduced, for a small area, to 4 inches, and the whole seam thus shrinks to 2½ feet, but in adjacent property the coal measures 3 feet 4 inches, the lower bench being 1 foot thick. The Zanesville glass-houses obtain their fuel from these mines. The composition of the coal, as sampled for the survey by Mr. E. C. Downerd, is as follows:

Coal Dale Coal (Lord).

Moisture	4.82
Volatile combustible matter	40.91
Fixed carbon	48.67
Ash	5.60
Total	100.00
Sulphur	3.57

These figures put the coal in line with that of the seam throughout Eastern Ohio generally.

Six miles north of Zanesville, on the Cincinnati and Muskingum Valley Railway, Mr. David Matthews is carrying on mining on quite a large scale for this region. He employs an average of 25 miners for the year. Following the coal eastward from its outcrop in the river hills, the workings are always upon the dip. The water is removed from them by siphons. Formerly the slack was coked at this point, and the coke was used in iron making in Zanesville. The coke must have been high in sulphur. Its production was not long maintained.

The general conditions of the seam from Zanesville northward have now been pointed out. Within the limits of Zanesville the coal is extensively mined, though in small banks that produce each but a few thousand tons in a year. A large acreage has already been worked out, but a considerable amount still remains. Zanesville has cheaper coal than any other city of its size in the State.

South of Zanesville the conditions of the seam are gradually changed. Following first the Muskingum Valley, we find the coal at its proper horizon, and with its normal characteristics in the river hills on both sides of the river, as far south as Taylorsville. Only country banks are found on the east side, but on the west side, which offers the advantage of working against the dip, and also of nearer approach to the river, there are a number of shipping mines. Several of them have inclines connecting with boat landings. Their product is in all cases shipped by the river, and mostly to McConnellsville and points southward.

The Owens mine, in Section 7, Brush Creek township, is the largest of this group. The seam here measures 3 feet 8 inches to 3 feet 10 inches, and occasionally rises to 4 feet, but from these measures several inches of partings must be subtracted. The quality of the coal is excellent. At Ballou's Salt Works, in Section 12, Brush Creek town-

ship, mining has been carried on quite extensively for many years. Salt boiling is now abandoned, but the mines are kept in operation for the river supply of coal. The seam is thinner than at the Owen's mine, not averaging more than 3 feet.

The direction of the river valley through Wayne, Brush Creek and Harrison townships is but little south of east, and consequently the fall of the strata in descending the valley is well marked. The coal seam that we are following has an elevation of about 200 feet above slack water at Putnam Hill. At Ballou's Landing it is only about 90 feet above the same level. It lies at the water's edge opposite the lower end of the Taylorsville lock. The seam here has the following structure:

False roof.	
Coal, slaty and inferior	16–18 inches.
Parting	2 "
Coal, lower bench	14 "

The seam is verging to its southern limit apparently at this point.

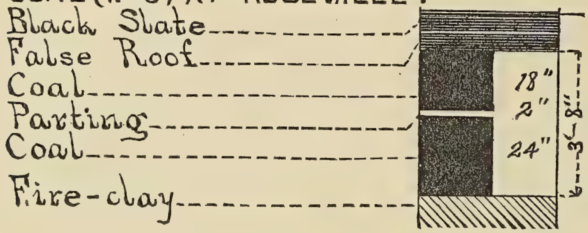
There is scarcely a farm between Zanesville and Taylorsville in which the coal has not been mined; there is not one in which the seam is not known to be present.

The greater thickness of the coal at the Owens mine has already been mentioned, but the further statement is needed, that it is the lower bench that makes the principal increase. At Zanesville and northward, this bench varies from 4 to 10 inches in thickness, but at the Owens mine it is 15 inches thick. The change is an important one, for the seam is soon to undergo the most marked transformation that is experienced by any coal seam in our entire scale, and this is the beginning of it. This lower bench maintains its increase even where the whole volume of the seam is diminished, as at Taylorsville, as has heen already shown.

In Brush Creek, Clay and the eastern half of Newton townships, the seam is constant in its occurrence. Wherever it is due, there it is found. In Sections 27 and 34, Newton township, shipping mines are opened on the line of the railroad. The Del Carbo mines have yielded a large amount of coal from both the Kittanning seams, but only the upper seam is at present mined here. Numerous farmers' banks are opened in the coal throughout this territory. At and about Roseville, in Clay township, mining is carried on upon a somewhat larger scale,

for the supply of the numerous potteries that are established here. The structure of the coal at Roseville is shown below:

FIGURE LXXV
STRUCTURE OF MIDDLE KITTANNING COAL (No 6) AT ROSEVILLE.



The change already referred to in the expansion of the lower bench of the coal seam is especially to be noted here. From the Owens mine, in the Muskingum Valley, to Roseville, the distance is about 6 miles. The lower bench has increased in this direction from 15 to 26 inches, while the upper bench has been reduced to the extent of 6 inches or more.

The coal of this field it will be better to consider in connection with the Perry county series, all the statements that are made in regard to the coals of Harrison, Clayton, Pike and Bearfield being applicable to the seams of clay and Newton township as well.

The Upper Freeport Coal.

This important seam can be followed from Guernsey county into and across Muskingum county. No basin of it has yet been discovered in the last named county that is fully equal in value to the Cambridge coal field, but there are several districts in which it has already a recognized value and importance, and one other, but little developed as yet, will be pointed out, which gives excellent promise.

The seam first makes its appearance in coming from the eastward, in Monroe township, where it exhibits the same fitful and inconstant character that it shows in the adjoining township of Guernsey county. It is said to be mined on a few farms near Otsego. The horizon can be traced with great distinctness throughout Adams, Madison and northern Washington, but the coal is, for the most part, thin and worthless. In the southern portion of Washington, in Perry, Wayne, Salt Creek, Harrison, Brush Creek, and Clay townships, it

appears as a workable seam, of considerable value. It is mined in many small banks, and in one or two of larger importance.

The Sonora Coal.

The most northerly of these centers of mining is at Sonora and in its immediate vicinity, on the western side of Perry township. The coal is chiefly mined in Sections 6 and 7, but a few openings are to be found in Section 8. The coal of Section 6 extends directly into Section 10, Washington, where it is also mined. On the farm of Mrs. Cullins, in Section 8, the coal is found 3 feet thick, and of fair quality. The seam is here 112 feet below the Cambridge limestone.

At Sonora, the coal runs from 2 to 4 feet in thickness. It is very irregular; owing to the frequent intrusion of the overlying Mahoning sandstone. The limestone that accompanies the coal is strongly developed throughout this region, and is frequently dug and burned in the small way for farmers' use. The most extensive coal banks in this neighborhood are on the lands of George Bowers, Moses D. Robertson and John H. Mangold. It does not seem probable that the seam will be found a fit basis for large mining operations in this neighborhood, but a local supply of considerable importance will long be maintained. The same statements will apply to the coal that lies directly south-east of Sonora, where mining in the small way has long been carried on.

The Alexander Coal.

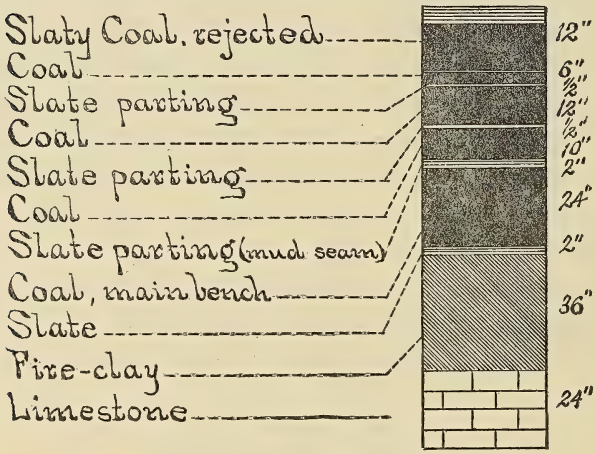
The best known basin of the Upper Freeport coal in the county is in the vicinity of Jackson, in the south-east corner of Washington township. The coal is mined here on quite a large scale, and is hauled into Zanesville as well as sold to the farmers of the adjacent country. The coal is known as the Alexander coal, having been worked on the largest scale and for the longest time by James H. Alexander. This field is spoken of as a distinct one, but in reality the Sonora coal and the Alexander coal belong to one and the same basin. This is clearly shown by the occurrence of small mines throughout the interval. The Sherlock and Shick mines are of this character.

In following the National Road westward from Jackson, the coal has been worked at various points, and it continues as far west as the land is found high enough to hold it. The coal has been principally

mined out from the Clark farm, two miles east of Zanesville, but the adjacent land of Adam Rock holds a small acreage on which mining is still going forward. Throughout this whole district, the coal lies very shallow. A great deal of it is got by stripping, and where mining is undertaken the character of the work is everywhere limited by the weakness and treachery of the cover.

The coal ranges from 3 to 5½ feet in thickness. The structure of the seam on the Alexander farm is shown below:

FIGURE LXXIIa
STRUCTURE OF UPPER FREEPORT COAL ON THE ALEXANDER FARM.



The numerous partings in the seam render it a dirty coal. To compete in the general market it would require thorough screening. The coal has a good name where it is used, but the limitations of area and of cover will prevent this immediate district from becoming any more important as a mining center than it now is.

Southward, throughout the northern half of Salt Creek township, the coal is frequently found of good volume, and is worked in many local banks. It is known as a four-foot seam. A considerable acreage, no doubt, exists here.

The same thing can be said of Wayne township. Near Duncan's Falls, a number of small mines are opened in this coal. The general thickness of the seam is 4 feet, and in quality it holds to the usual standard.

The Blue Rock Coal.

From Duncan's Falls, southward throughout the Muskingum Valley, the coal is easily followed as far as the south line of Section 20, Harrison township, a little below Gaysport, where it falls to the level of the river. Important mines have been worked near this point for many years, the coal being known as the Blue Rock coal, and finding its market along the river. The immediate cover of the seam is very heavy, reaching well up to the Pittsburgh coal. The hill above it consists in large proportion of the clays and shales of the Barren Measures, making a treacherous series to undermine. It was here that four miners were imprisoned, nearly 30 years ago, by a crush which closed up the entries leading to day. They were rescued alive after 14 days and 13 hours of imprisonment, during which time they had no food except a lunch or "check" that two miners had carried in on the morning of the day on which the crush occurred.

The Blue Rock coal, as it now appears, is in marked contrast with the general product of the seam elsewhere. It is a typical *pitch coal*, clear and bright to a higher degree than any other Ohio coal. In fact, it is nearly as clear as anthracite. No mineral charcoal is found in the present product of the mine. Its composition, as shown by Professor Lord's analysis of a single block, agrees with the description above. It is as follows:

Blue Rock Coal.

Moisture	3.50
Volatile combustible matter	46.44
Fixed carbon	45.87
Ash	4.19
Total	100.00
Sulphur	3.84

These figures show a remarkable coal, higher in volatile combustible matter than any other bituminous coal of our series, the cannels not being included. The proportion of sulphur is excessive, constituting the only drawback upon the otherwise high quality.

The seam carries, where normal, a regular thickness of 4 feet, but, as elsewhere, it is liable to sudden interruptions, some of which are

strikingly shown in the main entry of the present Blue Rock mine. The coal is here entirely cut out for many yards.

Much time and some money have been spent at various points along the valley, and especially on the opposite side of the river, in a vain search for the Blue Rock coal. The horizon of the coal is everywhere made clear, though not generally recognized, by its fire-clay and limestone, but of the coal itself not a trace may be left. This fact should be borne in mind in all investigations directed toward this seam. It was never universally distributed, like the Middle Kittanning, in its field. So far from being so, it is known to be unusually capricious and uncertain. In addition to the irregularity of original formation, the seam where once duly formed was afterward exposed to the accidents of quite a violent erosion. So coarse a sandstone as the Mahoning cannot be explained without calling into action strong currents for its transportation. From these two causes, viz., failure of uniform and continuous formation and waste of the basins that *were* formed by erosive currents, results the exceeding uncertainty of the Upper Freeport coal through a large portion of the territory in which it is due.

The Upper Freeport clay is worked at its proper level at Ballou's Landing, in Brush Creek township. It is here a non-plastic clay of good quality. It has been worked to some extent in the fire-brick factory at Putnam. The coal does not appear in immediate connection with the clay, but it has been found and mined on adjoining farms at its proper level.

The Brush Creek Basin.

The least known and least developed, but by far the most promising field of the Upper Freeport coal in Muskingum county, is included in Clay, Newton, and Brush Creek townships, and is rendered accessible by the valleys of Brush Creek and its tributaries. There is a possible important extension of it into Harrison township, as will be presently shown. The coal occupies, so far as can be determined by natural exposures, parts of Sections 1, Clay; 25 and 36, Newton; 7, 6, 26, 5 and 27, of Brush Creek townships, but boundaries for a coal field of this particular seam, when laid down in advance of careful exploration, are of little worth. The probabilities all seem in favor of a large territory for this Brush Creek basin. Throughout the area named, it gives all the signs of steadiness that can be asked. It is found where it is

due and seems unusually uniform and regular in its character. It does not vary much from a thickness of 4 feet in any of the numerous openings that have been made in the seam for local coal banks. At the Duvall banks, in Section 36, Newton, there are 4 ft. 4 inches of coal, overlain by 6 inches of cannel. Its quality also seems in all respects satisfactory. It is a bright, fairly clean coal, well jointed, cutting easily, and mining to good advantage. It is much freer from seams of shale and clay than this seam usually is. The regular black slate above the seam becomes locally a cannel coal, but of no great value. The coal is shown on the east side of the Brush Creek Valley in every farm for 2 or 2½ miles, through Sections 7, 5 and 27. It dips down under the heavy ridge that separates Brush Creek from the Muskingum River in Brush Creek and Harrison townships. Crossing this ridge to the eastward and descending toward the river valley by one of the branches of Blue Rock Run, the moment that we come to the level at which the coal could appear, we find the farmers mining it by stripping from the creek bottoms, the coal still holding a thickness of 4 feet. From this point on to the famous Blue Rock mines of the Muskingum Valley, which have been already described, the coal appears almost continuously, being everywhere counted a 4-foot seam. Where the change begins to occur, by which the present remarkable character of the Blue Rock coal is acquired, there are no present opportunities for learning, but the inference is a legitimate one that the Brush Creek coal extends under the divide until it unites with the Blue Rock field. In other words, these two fields belong to one and the same basin. If the proper exploration shall confirm this view, it is clear that we have here one of the largest and most promising of the Upper Freeport coal fields of the State, comparable in value with Salineville, Dell Roy and Cambridge. While the seam does not show as great thickness here as in the other chief centers of production, it seems steadier than elsewhere, and if this fact is established, it will more than compensate for the smaller measurement. It must not, however, be forgotten, that the seam has everywhere else, and even in this field, to some extent, suffered from the erosion due to the transportation of its sandstone roof, and much more irregularity than has yet been developed ought not therefore to surprise us, if it shall be hereafter disclosed.

The wide limits, provisionally assigned to the field, may also be proved incorrect by the application of suitable tests to that part of the

territory that is now inaccessible, but in any case, a very valuable and promising body of the Upper Freeport coal is already in sight in the Brush Creek Valley.

These statements complete the accounts of the Lower Coals of Muskingum county. While there is not a large mine in the county, the aggregate production is not insignificant, but the mining is of such a character as to escape public notice and record to a great degree. The possibility of larger mining interests has, however, here been pointed out.

COAL MINES OF PERRY COUNTY, NORTHERN AND CENTRAL TOWNSHIPS.

Under this head all of the coal mines of Perry county will be considered except those of the southern tier of townships, viz., Monday Creek, Salt Lick, Coal and Monroe, to which may be added the south line of sections of Pleasant township. The ground on which this separation is made is obvious. The last-named townships belong to the Hocking Valley field, constituting an important portion of what is known as the "Great Vein" territory, in which the Middle Kittanning seam (Coal No. 6) ranges from 5 to 13½ feet in thickness.

The general character of the district, now to be considered as a coal producing region, agrees very closely with that of Muskingum county, last described. The coal seams that possess economic value in Muskingum county are valuable also in Perry county, but to the three seams which furnish the main supply of the former county, viz., the two Kittanning coals, Nos. 5 and 6, and the Upper Freeport coal, No. 7, one other must be added, viz., the Lower Freeport coal (No. 6*a*). This is mined in Clayton, Pike and Pleasant townships of Perry county, to a small extent.

The geological range of Perry county is quite extensive. It includes the uppermost two hundred feet of the Waverly group, and it reaches to the level of the Pittsburgh coal, but that part of it, now under consideration, is chiefly confined to the Lower Coal Measures. This series has a full and geologically interesting development here, but

its economic values are limited mainly to the elements previously named. The general order is shown in the sections given in chapter I, pages 100–103.

The Sub-Carboniferous limestone has its best development in Ohio, in Perry and Muskingum counties. In Hopewell township, near Glenford, it has been worked for the Shawnee furnaces on a number of farms. Thence, eastward, along the valley of Jonathan's Creek, there are frequent exposures of it, until, near Uniontown and Newtonville, we find not less than 20 feet in the bed and walls of the creek. It is a very fine-grained homogeneous stone, sparingly fossiliferous, generally drab or light-buff in color, and, when skillfully worked, a building stone of great beauty and excellence. It has been employed to good advantage in Zanesville, in the construction of the new Court House and also in the new Opera House front.

The Sub-Carboniferous limestone is sometimes overlain by the Carboniferous Conglomerate and sometimes by the ordinary strata of the Lower Coal Measures. The Conglomerate is found in its best development in Hopewell township, where its maximum measurement is 60 feet. It carries pebbles in large quantity, and in places a few feet of it are pure enough to furnish a glass sand of approved quality. It is now quarried and crushed for this use by J. Downerd and Son, at Chalfant's Station.

As usual, this stratum is exceedingly inconstant and irregular. Aside from the township named, it makes no appearance in the geological series of the county.

The Lowest Coals.

The Sharon coal horizon is often marked by a bed of black shale lying above the limestone, but no deposit of coal of any value has been found at this level, and in none of the records of the borings made for salt or oil in the county has any deep coal ever been reported. A single exception may be needed for a tract of 25 to 30 acres on the farm of W. B. Taylor, Sect. 14, Hopewell township, in which a workable coal was found just above the Sub-Carboniferous limestone. So far as can be judged from all the facts of the outcrops of these lowest horizons, the Sharon coal is not likely to be found in Muskingum, Perry or Hocking counties, in valuable condition, and no really workable bed of the Quakertown coal (No. 2) is known in these limits. The latter is

probably represented by a small and uncertain seam, which is frequently met, 40 or 50 feet below the Lower Mercer limestone. It is sometimes opened by stripping in ravines or on hill slopes, but it never justified mining in a methodical way.

Several borings have recently been made in the vicinity of Junction City, in search of a lower coal. They were begun at a horizon about 50 feet below the Lower Mercer, and passed in their descent through several streaks of coal and fire-clay. The borings were made by Mr. Philip Patton, of Canal Fulton. He has kindly furnished to the Survey the records of these wells. One of them is given herewith:

Record of Boring near Junction City.

12 ft.	Made earth.
5 ft.	Gray Shale.
½-ft.	Coal and slate (Quakertown ?).
20 ft.	Fire-clay.
10 ft.	Light-gray Shale.
12 ft.	Dark Shale.
1 ft.	Soft black slate and coal (Sharon ?).
3 ft.	Fire-clay.
6 ft.	Sand rock (Conglomerate ?).
15 ft.	Dark Shale.
2 ft.	Black slate, hard (Maxville horizon ?).
2 ft.	Fire-clay.
30 ft	Light-gray Shale.
5 ft.	Dark Shale.
13 ft.	Flagging, soft and hard.

The lowermost 50 feet undoubtedly belong to the Waverly formation, the exposures of which are found in all the region to the westward.

The Lower Mercer coal is shown in numberless sections. The limestone of this series may be said to be universal, and the ores are also very widely distributed. The coal is occasionally wanting, but, as a rule, there is at least a thin streak of it under the limestone. Nowhere in Perry county is the seam known to be thick enough to fairly justify mining, but small openings are occasionally made to it. Its quality, where seen, is generally poor.

The same line of remark applies to the other limestone coals, viz., those beneath the Upper Mercer and the Putnam Hill limestones, which are known respectively as No. 3*a*, and No. 4. Both are present in numerous sections, and neither has much economic value in any instance.

They are occasionally mined in a very small way by stripping in favorable locations.

The Clarion coal that has long been missed from the series in coming westward is found again in Perry county, in a considerable number of sections. It lies 15 or 20 feet above the Putnam Hill limestone, and is locally recognized as No. 4*a*. It is not known to reach 2 feet in thickness at any point. One and a half miles N. W. of New Lexington it is found 22 inches thick. The quality of what coal there is, is good.

The Kittanning Coals (Nos. 5 and 6).

These two seams constitute almost the entire reliance of that part of Perry county now under consideration. They are 20 to 30 feet apart. The upper seam is, as usual, steady and uniform both in quality and in distribution; the lower, though much less regular, finds in this field one of its best developments in the State, and attains great economic value. These coals have both been mined within the corporate limits of New Lexington, the county seat, and are accordingly known as the Upper and Lower New Lexington coals. These names have been applied quite widely to the coals in our geological literature, and are in reality among the commonest designations of the Kittanning coals in Ohio.

These seams retain the same general characteristics by which they are marked in Muskingum county.

The Middle Kittanning Coal (No. 6).

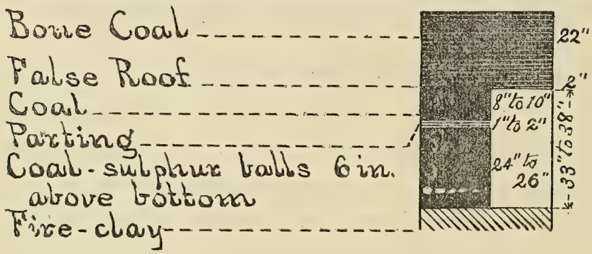
The upper seam ranges in thickness from 3 to 4 feet of merchantable coal. Above this portion of the seam, 10 to 20 inches of impure coal, known as bone coal, are invariably found. This bone coal burns readily, but yields an excessive quality of ash, and is also sometimes high in sulphur. An analysis of a single set of samples, made for the survey by Professor Lord, yields the results given below. The samples were taken from the mine of J. F. Sheerhan, at Ferrara, on the Ohio Central Railroad:

Moisture	4.52
Volatile combustible matter	36.43
Fixed carbon	37.39
Ash	21.66
Total	100.00
Sulphur	4.76

A coal of this character cannot, of course, be put into market under present conditions. In mining, the bone coal is generally taken down in entries, but not in rooms. In all cases where the bone coal is taken down, the entries afford room for a four and a half-foot mule, and often they give fully 5 feet of headway. The general structure of the seam is shown in the appended diagram:

FIGURE LXXIX

STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT J. & F. SHEERHAN'S MINES CLAY BANK STA.



The coal of the seam mines in blocks of only moderate size, but it bears handling fairly well, and yields no excess of slack or nut coal.

The character of the coal agrees exactly with the better phases of the Coshocton and Zanesville coals. It ignites easily, burns with a long and abundant flame, cements slightly in the fire, and yields a purple or chocolate-colored ash, of which the amount is relatively small. It is a favorite domestic coal wherever it is introduced, but its special adaptation is to the production of steam. It is highly approved and quite largely used as locomotive fuel. Its general constitution can be seen from the following analysis made for the survey by Professor Lord. The coal came from the largest mine of the district, viz., that of S. & J. Jones, McLuney Station. The sampling was done by Mr. E. C. Downerd:

Composition of Middle Kittanning Coal (No. 6), at McLuney's.

Moisture	5.95
Volatile combustible matter	41.87
Fixed carbon	48.21
Ash	3.97
Total	100.00
Sulphur	1.65

This analysis shows a coal of excellent character but it is believed to fairly represent the coal of a large area. There are mines in the field the quality of whose output is decidedly inferior to the quality shown above, but there are very many that come fully up to this standard. The only point, if any, in which the foregoing analysis overstates the composition of the better grades of this seam within the district, is the percentage of sulphur. It will be safe to count on 2 per cent. of this element. In all respects, as will be seen, the analysis represents the Middle Kittanning coal in its characteristic phases.

The Lower Kittanning Coal (*No.* 5).

This seam is not as constant in character as the seam last described. It is not only inconstant in its appearance in the sections where it is due, but, when it does appear, it is not always with the same constitution, physical or chemical. Still it can be described in general terms as a white ash, open-burning coal, with about the same percentage of fixed carbon, volatile matter and sulphur as the coal above it. It is a little higher in ash, as a general thing, and is counted more lasting in the fire. Its normal thickness is between 4 and 5 feet, and within this district it attains its full thickness at many points, becoming a proper and valuable basis for mining. It is commonly known as the "4-foot seam." It frequently occurs as an undivided seam, and when found at its best, it is one of the brightest and cleanest coals of this portion of the State. Its irregularities are mainly in the floor, which is a hard black slate above a fire-clay. This floor rises and falls in ridges and troughs, which complicate the drainage of the mines to some extent.

These two seams will now be briefly traced from the eastern county line through the several townships that hold them, and their present development as sources of fuel will be shown.

Madison Township.

The Kittanning coals occupy a small part of Sections 22, 27, 33 and 34 in the south-east corner of the township. The lower seam is also reported to occupy a small area in the high grounds of Sections 15, 10, 3 and 4. The coal is of but small account in this last-named area, but the clay of the seam, as here identified, has been worked to a considerable extent, and has always been counted of superior quality.

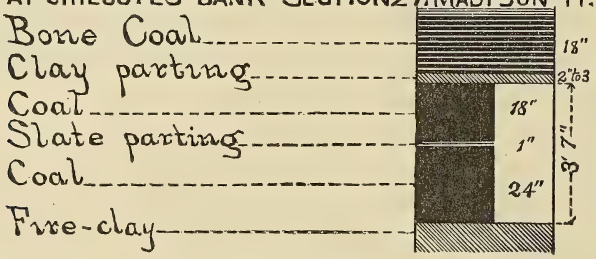
The Hazlett farm, now belonging to Davis Woodruff, is reported to

furnish the best clay of this whole district, the clay being hauled for long distances to the Muskingum county potteries. The seam of clay is 5 feet thick. On the D. Crossen farm, Section 27, the clay is said to assume its hard and non-plastic condition, but there are not any openings to it at present.

On the Chilcote farm, now A. E. Henderson's, Section 27, both the coals are worked, on a large scale, for country banks. The Middle Kittanning or upper seam has been mined for many years to supply fuel to a considerable scope of country to the westward. The quality of the coal is good, and the seam is of full thickness. Its structure and dimensions are shown in the appended figure:

FIGURE LXXXVI

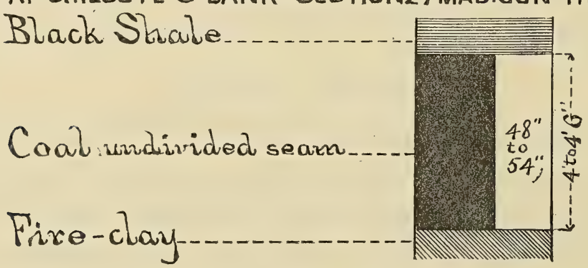
STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT CHILCOTE'S BANK SECTION 27, MADISON TP.



The lower seam has also been worked here to a considerable extent. It measures 4 feet 6 inches in thickness, and shows no partings. It is counted equal in value to the upper seam. Its structure is shown in the appended diagram:

FIGURE LXXXVII

STRUCTURE OF LOWER KITTANNING COAL (No. 5) AT CHILCOTE'S BANK SECTION 27 MADISON TP.



The same coal is worked on the farm of D. Crossen, Section 27, where it has a thickness of four feet, rising occasionally to 4 feet 6 inches, and also on the farm of Leonard Reddick, in Section 34.

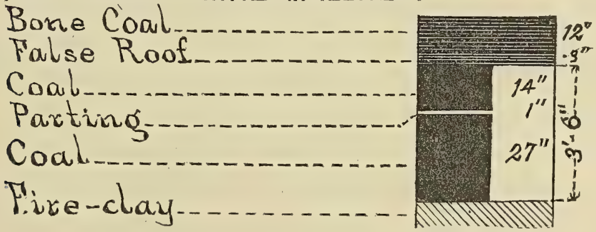
No large mining operations are likely to be undertaken in this township, but the same sort of production that has existed here for a generation is likely to be continued for many years to come.

Harrison township.

The Middle Kittanning or upper seam has been and is mined more extensively in this township than in any other of the northern townships of the county. Not less than 12 sections of the township are either traversed by or are directly tributary to the Cincinnati and Muskingum Valley Railway, and in half of these, coal has been mined on a large scale. In addition to this, it can be said that coal is mined for local use in every section of the township. In fact, this coal seam constitutes a universal sheet throughout Harrison, most of Clayton, Pike, Bearfield, and the northern half of Pleasant townships, being present literally everywhere, save only as the accidents of erosion to which the present topography is due, have removed it. Not a "want" or break in natural continuity is known throughout this field. In thickness it ranges between 3 feet and 4 feet of marketable coal.

The character of the coal has been already shown in the analysis given on page 888. These figures are thought to represent fairly a large part of this district. The samples analyzed came from the mines of S. and J. Jones, McLuney Station, the largest mines of the township. The section of the coal is given below:

FIGURE LXXVI.
STRUCTURE OF MIDDLE KITTANNING AT JONES' MINE McLUNEY.



The coal mines here in good shape and size. The main entries all admit 4½-feet mules. The price of mining is generally 10 cents above that paid in the thick coal just south of this field. The cost of blasting powder is about the same as in the thick coal. There is little waste in the seam. The lower slate is easily separated, and there is nothing else to make trouble. About 50 miners are steadily employed here, the

output being chiefly used for the locomotives of the railroad. These mines are located in Section 32. In Sections 20, 21, 29, 31 and 36, shipping banks have also been worked for a number of years. The mines of M. & P. Tague, in Section 20, are the largest in the township, after the Jones mine. All of the conditions noted above are repeated here. A successful business has long been maintained by this firm. In the winter season, seventy-five miners find employment here.

In Sections 31 and 36, a considerable acreage has been exhausted of the lands lying nearest to the railroad, but a large body of coal remains that is easily available. The mines located here are known as the Tunnel Hill mines. The structure of the seam agrees in all respects with that given for the McLuney mines, except that the bone coal in the roof rises to 16 inches in thickness.

It is unnecessary to go into more details concerning this seam in Harrison township. There is a large and valuable supply of excellent coal, which offers a fair reward to properly managed mining enterprises, wherever transportation is possible. It is sure to be drawn upon in the near future, for in the work of mining coal, steadiness and persistency, with only moderate thickness, furnish in reality a better business basis than large but inconstant volume in the seam worked.

The Lower Kittanning coal, or No. 5, is everywhere due throughout the areas occupied by the upper seam, but there are only a few mines now open in it, and there is no reason for believing in any large development of it within the township limits. Its clay is present in valuable condition and quantity where the coal is wanting. In Section 8, several mines in this seam have been worked for a number of years. The coal is, as usual, inconstant in thickness, ranging from 2½ to 4½ feet. The quality is reported to be fair, but the product of the mines is insignificant. In Sections 4 and 9, the Lower Kittanning coal has been opened in years past, but it did not justify continuous working. In Section 25, a mine is in operation in this seam on the farm of C. Sweeny, the coal running much more regular and steady in this direction.

The clay industry of Harrison township is very important, but this has been treated in another chapter. There is also a considerable showing of ore throughout the township, but such trials as have been made do not warrant great expectations of value from this source. Most of it comes from the limestone horizons, and especially from the Upper or

Putnam Hill limestone, which is well developed throughout the township. The limestone can be readily obtained in large enough quantities to meet all local demands.

Clayton Township.

Hitherto, the coal of this township has been available only for local supply, but the extension of the line of the Columbus and Eastern Railway through the central portions of the township is opening a field of much promise. Unlike the township last described, both the Kittanning coals are in fine development here, the upper holding the same characters that have been previously assigned to it, and the lower seam rivaling it in value. From present appearances, one of the valuable basins of the Lower Kittanning coal in Central Ohio is likely to be found here.

A section representing a considerable part of the township is to be found on the lands of J. S. Nixon, near Rehoboth. It is as follows:

Blossom of Brush Creek Coal (No. 7*a*).	
Not exposed	35 feet.
Ore	1 foot.
Fire-clay	10 feet.
Horizon of Upper Freeport Coal (Black band ore)	———
Sandstone	2 feet.
White clay	5 "
Shelly sandstone	10 "
White clay	5 "
Soft sandstone (Upper Freeport)	30 "
Blossom of Lower Freeport coal (No. 6*a*)	———
Fire-clay	14 feet.
Ore, horizon of Lower Freeport limestone	———
Brown shale	30 feet.
Middle Kittanning coal (No. 6)	4½ "
Brown shale with ore balls	28 "
Coal No. 5	4 "
Fire-clay and shaly sandstone	13 "
Baird or Hanging Rock ore (Ferriferous limestone)	1½ "

The Kittanning coals are due in nearly all parts of the township. Both are worked in farmers' banks in at least three-fourths of the sections. They are wanting altogether in but two Sections, viz., 6 and 7, but in Sections 1, 2, 3, 5, 8, 17, they have but little area and value.

The line of outcrop passing south from Madison enters Clayton township in Section 5. On the farm of William Pettit, Sen., in this section, the lower coal has been worked. Its thickness is reported to be 4 feet and 7 inches, but no opportunities for measurement are now afforded. The Clarion coal (No. 4*a* of the local scale) is also reported 15 or 20 feet below the seam named above. It was found 15 inches thick, which is about the usual measurement.

In Section 9, both coals have been worked in several small mines. They are found in their usual condition.

The Lower Freeport coal has also been opened in this section by T. F. Skinner, who found it an undivided seam, 3¼ feet in thickness, and with a roof of gray shale.

On Sections 11 and 12, the Lower Kittanning clay has been mined to some extent on the farms of David Amrine and R. L. Henderson for the two potteries established at Saltillo. Coal is also mined in both sections.

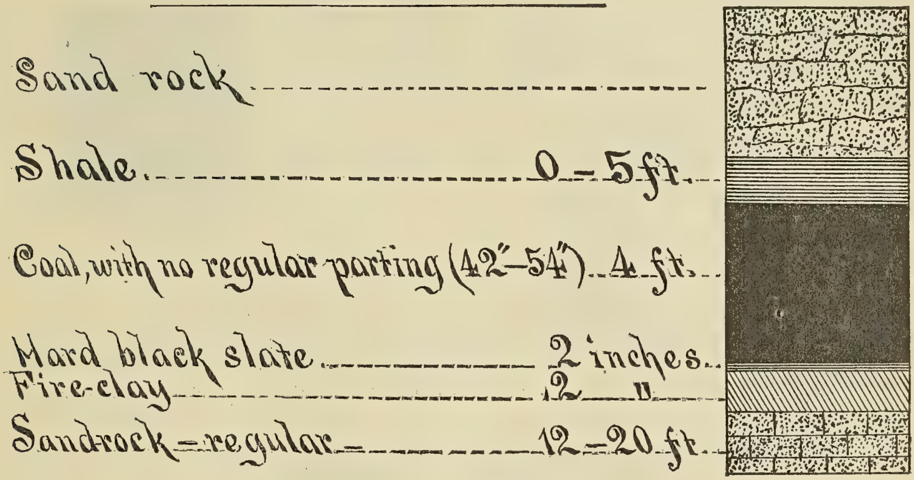
On Section 14, directly south of Section 11, the Lower Kittanning Coal (No. 5) is mined on the farm of Mrs. Ann B. Mulroy. A measurement taken here at the head of the entry showed 3 feet 5 inches of coal in a solid bed, without partings. The upper seam is also present throughout all the territory referred to.

The New Mines of the Columbus and Eastern Railway Co.

It is on this section that the Columbus and Eastern Railway has established its present terminus, viz., the village of Redfield. Three mines, with excellent equipment, are now being opened at this point, two in the lower seam and one in the upper.

The Lower Kittanning coal here exhibits its normal phases. It is a bright, handsome coal, burning freely and holding fire well. It has a somewhat uneven floor, carries an average thickness of a little less than 4 feet, is undivided, except that a thin streak of bone sometimes appears near the top. The roof is unusually strong and safe. Its structure and surroundings are shown in the accompanying figure:

FIGURE LXXXVIII
STRUCTURE OF LOWER KITTANNING COAL, (NO. 5.)
AT REDFIELD.



The composition of the seam at this point is somewhat below its best phases, so far as can be judged by a single analysis of hastily selected samples.

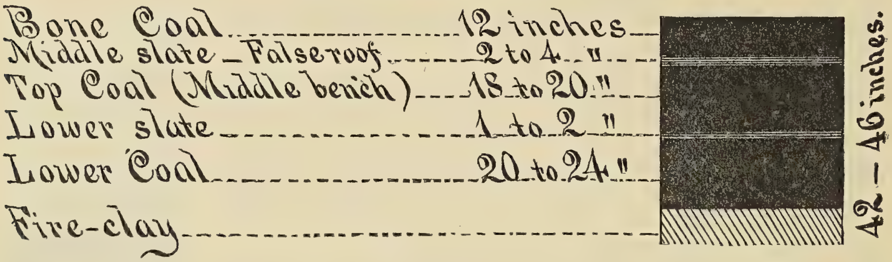
Mining is begun at Straitsville prices, but Lechner machines are to be introduced at once, by which the seam can be more economically handled. Rooms are worked 18 feet wide, and pillars of 10 feet are left. The room roads are run along side of the rib to make the final drawing easier. The face and ends lie nearly to the cardinal points. The end joints are much closer and less regular than the face. The coal requires about 1 keg of powder to 50 tons. It mines in fair sized blocks, and has good strength. It is being introduced as a domestic coal. There is a large acreage in this field. It seems certain to prove one of the most important basins of Lower Kittanning coal in the State.

The Middle Kittanning coal is opened also by the company at the same point. The coal is in all respects regular and characteristic. Its structure is shown in the following diagram: (See page 896.)

There is a large and well proved acreage of this seam tributary to the railroad. It can be counted upon to supply 42 to 46 inches of coal of good quality, especially for steam production.

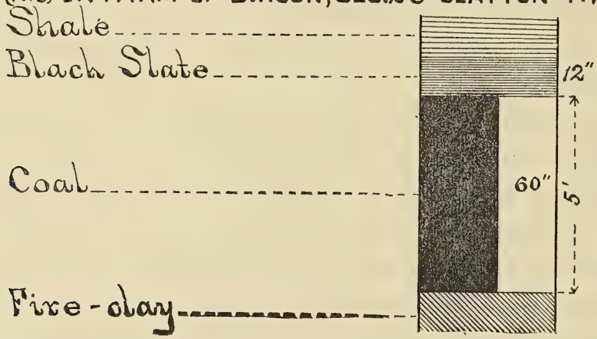
In the northern portion of Section 26, on the land of Bernard

FIGURE LXXXIX
STRUCTURE OF MIDDLE KITTANNING COAL (No. 6)
AT REDFIELD



Noon, the Lower Kittanning coal has been mined for many years for local use. The seam has not been found here less than 4 feet in thickness, and the quality is good. Its structure is shown in the accompanying figure:

FIGURE LXXXIV
STRUCTURE OF LOWER KITTANNING COAL
(No. 5) ON FARM OF B. NOON, SEC. 26 CLAYTON TP.

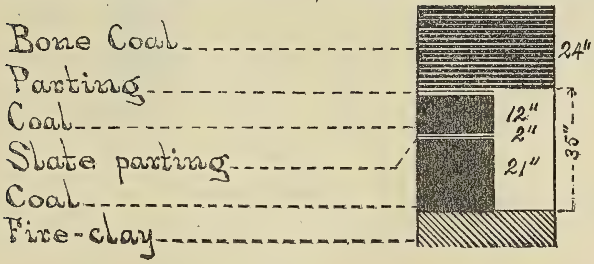


The same coal seam is now and has been, for many years, worked on Section 27. On the Pace farm there is a fine showing of the coal, 4 feet and more in thickness, and very bright and clean.

About Rehoboth, also, on Sections 33 and 34, the two Kittanning coals and the Lower Freeport are all now worked. The Lower Kittanning coal shows in E. Teal's banks, which are the largest of the neighborhood, a little less than 4 feet of coal. The Lower Freeport coal (No. 6*a*) is opened and worked to a small extent on the R. Bennett farm. It measures about 3½ feet in thickness, but the quality is inferior to that of the seams below it.

At Isaac Denny's bank, in this section, the upper coal (No. 6) has the structure shown below:

FIGURE LXXXII
STRUCTURE OF MIDDLE KITTANNING COAL (No 6)
AT ISAAC DENNY'S BANK, SEC.33, CLAYTON TP.



In Section 19, the Lower Kittanning coal, No. 5, is worked on Adam Acker's farm, as is also the Middle Kittanning, No. 6. The latter measures 4 feet 7 inches, of which 15 to 18 inches belong to the bone coal of the roof. The lower seam is 35 feet below the upper. Its quality is shown in the following analysis of the seam, as sampled by Mr. E. C. Downerd for the Survey:

Lower Kittanning Coal, Section 19, *Clayton—Adam Acker's Mine* (*Lord*).

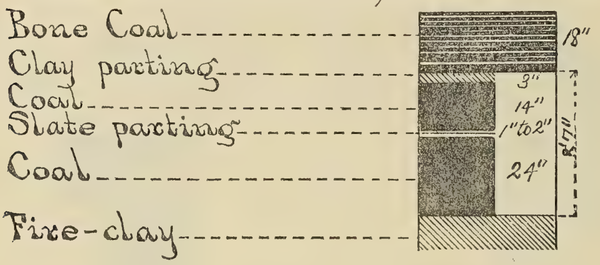
Moisture	6.04
Volatile combustible matter	42.66
Fixed carbon	45.55
Ash	5.75
Total	100.00
Sulphur	1.92

A considerable part of the coal supply of Reading township is obtained from these banks, the balance being derived from the four south-eastern sections of Reading, viz., Sections 25, 26, 35, 36, through which the Kittanning coals extend, occupying less than 1,000 acres.

In Section 29, at Mathew Clayton's bank, the upper coal has the structure shown in the figure that follows: The coal has long been mined here:

FIGURE LXXXIIII

STRUCTURE OF MIDDLE KITTANNING COAL No 6)
AT MATTHEW CLAYTON'S BANK, SEC. 29 CLAYTON TP.

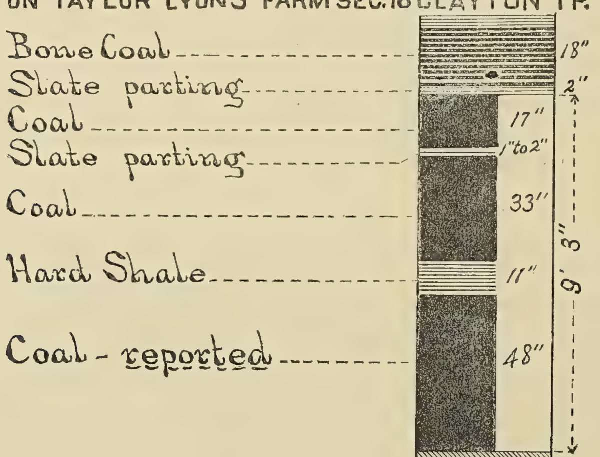


In Section 20, on Samuel Brown's farm, the upper coal shows a slight deviation from the normal structure, 6 inches of cannel coming in immediately above the lower slate, which is here represented by 1 inch of mineral charcoal, or a so-called "soot vein."

A still greater anomaly is reported in the same seam, as shown on Taylor Lyon's farm, on the east line of Section 16. The structure of the coal (No. 6) at this point is represented in the appended diagram, the figures as to the lower portion being taken on the testimony of the proprietor:

FIGURE LXXXV

STRUCTURE OF MIDDLE KITTANNING COAL (No 6)
ON TAYLOR LYON'S FARM SEC. 16 CLAYTON TP.



From this figure the following facts will be seen, viz., that the regular seam, which occupies the upper part of the section, has unusual

thickness, the lower bench measuring 2 feet 9 inches, and the upper, 1 foot 5 inches, with the usual thickness of overlying bone coal. This part of the seam is open to measurement. The anomaly consists in 40 inches of coal, which, as is claimed, is found below the regular seam, and separated from it by an interval of 20 inches, 11 inches consisting of hard shale. There seems no reason to doubt that there is at this particular locality some abnormal facts in the section, but, from an unaccountable lack of enterprise, no proper exhibition of the compound seam has been made, at least in late years. The expenditure of a few dollars would furnish a full-faced section of the whole structure, and set at rest all questions as to the facts. Until such a section is furnished, it will be safe to conclude that the lower coal makes no addition to the value of the field. Claims are made of the same doubled seam on adjacent farms, but if the owners have not faith enough in the claims to properly test them, they cannot complain of the skepticism of the public. The one established fact in which real and demonstrable value lies, is in the thickness of the main seam, which is greater here by several inches than elsewhere in the township.

Enough has now been said to demonstrate the value and importance of the Kittanning coals in Clayton township. The coal of Reading township, in the 4 sections already named, exactly corresponds to the facts as now described in Clayton, but it lies high in the hills, and therefore occupies but a small area and need not be further treated here.

Pike Township.

The coal of Pike township is mined almost exclusively from the Kittanning seams, and mainly from the upper (No. 6). The only exception to be made is that the Lower Freeport coal has been worked in years past in one or two mines. The two coals of the Kittanning series get the names, by which they are as widely known as by any other in Central Ohio, from New Lexington, in this township, where both have long been worked. There are but few and small areas in the township from which they have been removed by erosion, and the upper seam is, so far as is known, always present where it is due. It is unnecessary to repeat the statements as to the character of the coals. All of the facts given in connection with the adjoining townships apply here without qualification. There is scarcely a section in the township in which the upper coal (No. 6) is not mined either for neighborhood

supply, or, in a few cases, for the general market. In the westernmost sections the coal is rising to its final outcrop, and often has light and inadequate cover. In the eastern and southern sections it is buried deep, but not so deep that it is not easily accessible from the main valleys that are cut down to and slightly below its level. We may be sure that all of this steady and excellent seam will be called for, and will be taken by large mining operations, at no very distant period. A score or two of years, at most, at present rates of production, will clear out all of the more inviting fields of thick coal that are now known, and then the demand for such fields, as Pike township presents, will certainly arise.

The thickness of the coal throughout the township averages 3 feet and 2 or 3 inches. The proportion of it that is known that falls below 3 feet is very small. A large acreage is to be found that reaches just 3 feet. A considerable part of the territory will yield 3 feet and 4 to 6 inches of clean coal.

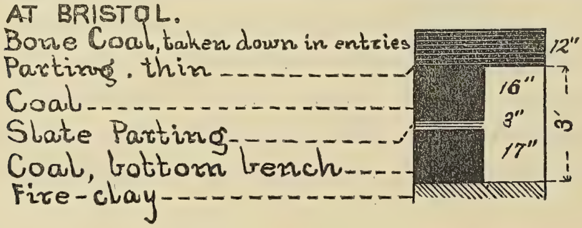
The Lower Kittanning coal (No. 5) has some excellent basins in the township, but the seam appears to be less extensive here than in Clayton township. Near New Lexington, and, indeed, within the corporation limits a valuable body of this seam is known. It is as highly valued as the upper coal for ordinary use. It holds its usual thickness of 4 feet and over, when at its best, and it is also characterized by the usual unsteadiness of the seam.

It is to be noted that the Clarion coal (No. 4*a*) of the local section is almost everywhere present in this township where its horizon is seen. It belongs about 15 to 25 feet below the Lower Kittanning. It rarely exceeds 15 inches in thickness.

On the western side of the township, in Sections 18, 19, 30 and 31, the Middle Kittanning seam has been long and largely worked for shipment on the Shawnee branch of the Baltimore and Ohio Railroad. The section of the coal at this point is shown in the following diagram:

FIGURE LXXX

STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT BRISTOL.



The coal, when taken out, leaves a three-foot hole in the ground, and when the bone coal is also removed in entries, there is 4 feet of space.

The quality of the coal at several of the mines is somewhat coarser than is usual in the seam. It yields a large amount of ash, which is no longer of the purple color that marks the northern phase. Much of the coal produced is used for locomotive fuel.

The mines located along the road between Bristol and McCuneville are the following, viz.:

Maholm Coal Company,	present output,	9	cars	per week.
Pimlott and Hall,	"	9	"	"
Bristol Mining Company,	"	9	"	"
Levi Rarick, new mine,	"	6	"	"
Edward Simpson,	"	3	"	"
J. C. Hamilton,	"	20	"	"

The price of mining generally ranges 25 cents per ton above the price paid at Shawnee. A miner will average about 2 tons of clean coal per day. The screens in use are mainly 1 inch between the bars, but a good deal of coal is sold as "run of mine." The entries are not in all cases made high enough for mules.

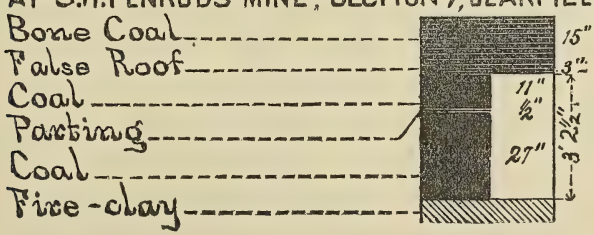
The Upper Freeport horizon is well shown in this neighborhood, but as a source of iron ore rather than of coal. The blackband deposits of this immediate neighborhood have been referred to on page 408.

Bearfield Township.

The same line of remark applies to Bearfield township, so far as its north-western quarter is concerned, as to the township last described. The Middle Kittanning coal, No. 6, is opened on every farm where its

FIGURE LXXVIII.

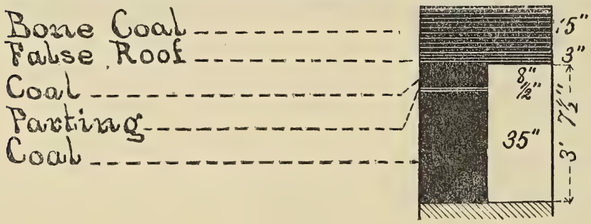
STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT S.H. PENROD'S MINE, SECTION 7, BEARFIELD.



horizon is exposed in the valleys of the South Fork of Jonathan's Creek and its chief tributaries. Its structure is shown in the appended figures, which represent the coal from S. H. Penrod's mine, on Section 7, and from Robert Moore's bank, in Section 8.

FIGURE LXXVIII

STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT R. MOORE'S MINE SECTION 7, BEARFIELD.



These figures are sufficient to show the wonderful persistency of this seam in all the details of its structure. Its chemical character is equally fixed and stable.

The lower coal, No. 5, is at the disadvantage of lying a little too low in all the valleys to be worked to full advantage in farmers' banks. It is almost everywhere below the level of high water, and in many cases below low water. If banks are opened in it, they can be reached only in the summer months, when least mining is to be done. This condition of things carries with it no disadvantage when mining is begun in any large and thorough way, but it is enough to discourage the only kind of work that now finds place here. Consequently this seam remains unproved in most of the township, but it is known to exist in workable volume on Sections 5 and 7, at least. Large and valuable basins of it can reasonably enough be looked for in this township, inasmuch as such basins are known to exist in the adjoining territory.

Pleasant Township (Southern Tier of Sections excepted).

The Middle Kittanning coal is exposed in the valleys that traverse the north-western sections of this township. The lower seam is nowhere above drainage. The Lower Freeport coal (No. 6*a*) has one of its best developments for this entire region at and about Moxahala, where it has been extensively, though not very successfully, worked.

The main development of the Middle Kittanning coal in this township is along the line of the Ohio Central Railway, from Clay Bank

Station southward to Moxahala. There are several shipping mines within this territory. The largest are those of the Sheerhan Brothers and of J. C. Elder.

The composition of the Sheerhan coal is given in the following analysis made for the Survey (Lord):

Moisture	5.21
Volatile combustible matter	40.59
Fixed carbon	46.85
Ash	7.35
Total	100.00
Sulphur	3.95

The composition of the bone coal from this mine has been given on an earlier page. The quality of the seam at this point is not equal to that of the seam at large according to these figures, but it is probable that a local modification only is indicated by them. The lower bench of the coal is a rich-burning tarry coal, and the whole product is readily sold by the side of the coal of the Sunday Creek Valley.

The seam has been opened on every farm between the south line of Section 15 and Moxahala. At the latter place it has fallen a little below the level of the valley, but has been opened here and even in a small way at various times within the last few years. It holds the characters already described until it passes under the Moxahala divide, being, up to this limit, a red ash, moderately cementing, rather sulphurous coal, with a thickness of 3 feet of marketable product, and covered by 18 to 24 inches of a slaty coal, called bone coal, too high in ash to be sold as good fuel. When it emerges from cover, 3 miles to the southward, in the deep troughs of Sunday Creek, a very surprising change is found to have been wrought in it. It is now a white ash, open-burning coal, low in sulphur, and ranging from 8 to 13 feet in thickness. The lower and middle bench, however, remain easily recognizable, the former, indeed, but little changed in thickness, and less changed in character than the other portion of the seam. The development of the upper section is, in reality, the most important element.

At Moxahala, the largest development and the most extensive workings of the Lower Freeport Coal (No. 6*a*) in the county, are to be found. This seam is here known as the Fowler coal.

An instructive section can be found at Moxahala and in its im-

mediate vicinity. The elements are as follows, viz.: Clarion coal and the two Kittanning coals (found in drilling), the two Freeport horizons, the Brush Creek coal, the Cambridge, and the Ames limestone. The measurements are as follows:

	Ames limestone—	
	Interval	80 feet.
	Cambridge limestone—In two benches, 8 feet apart—	
	Interval	43 "
	Brush Creek coal No. 7*a*)—thin, but constant—	
	Interval	50 "
	Upper Freeport coal—Black band horizon—	
	" " limestone and clay—sour apple ore?—	
	Interval, including Upper Freeport sandstone	25–50 "
	Lower Freeport coal—(No. 6*a*)—Fowler Coal—	
	" " Clay—Moxahala clay—	
	Interval	22–30 "
	Middle Kittanning coal (Upper New Lexington), (No. 6)	
	At level of low water—4½ feet, including bone coal.	
	Interval	30 "
Found in drilling.	Lower Kittanning coal (Lower New Lexington), (No. 5)	
Found in drilling.	Reported 4½ feet thick.	
Found in drilling.	Interval	21 "
Found in drilling.	Clarion coal (No. 4*a*), 18 inches thick.	

In the approaches to the railroad tunnel, south of the village, there is a characteristic exposure of the Upper Freeport horizon, the coal, however, being wanting. The clay and limestone are shown in full force. The coal comes in upon the south side of the tunnel, where it has been mined by the Ohio Central Coal Company, the mine being known as No. 2.

The Fowler seam, at Moxahala, has been thoroughly tested in all ways as a basis for mining and as a source of fuel. The Moxahala Furnace made use of it for a number of months as the sole supply of the furnace, and also as a shipping mine for the general market.

It is 5 feet thick, when in its best conditions, in the Moxahala mine. It is not, however, steady in thickness. It is very dry-burning at this point. It has not an excessive amount of ash, but it is high in sulphur. As a furnace fuel, it was a failure, under all the conditions to which it was subjected. Too dry to coke in the oven, and too sulphurous to use raw, it was charred in the open air, to expel the sulphur in part, but no sufficient relief from this deleterious element could be secured, and the record of the furnace while depending on the furnace mine was very unsatisfactory.

The coal mines well and bears transportation fairly well. It cannot, however, compete in market with the Middle Kittanning seam, from either north or south of the Moxahala divide, under present conditions.

Jackson Township.

The coal seams and mines of Jackson township remain to be briefly noticed in this general division of the county.

The lower seams make the same impotent and valueless showing that has been already described in other townships. Nothing that deserves the name of mineable coal is found until we reach the Kittanning horizon.

Reference has already been made to the section recently obtained at Junction City in the deep wells that have been drilled there. In the surrounding country also, the second seam of coal or the Quakertown seam is frequently shown. It sometimes reaches two feet in thickness. It is locally known as the Mohler coal, having been mined to a small extent on the farm of Mrs. B. Mohler, Section 30, Falls township, Hocking county. A few tons are occasionally quarried out of its outcrops. It is nowhere mined.

The Lower Mercer coal is generally less than a foot in thickness. The Upper Mercer is below 20 inches in thickness in all places where it is seen. It is known in some neighborhoods as the "16-inch seam."

The Tionesta coal (No. 3*b*) is known in this township as the *Cannel seam*. It lies about 45 to 50 feet above the Lower Mercer limestone, which is a stratum that every one knows, and which every one who attempts to trace the geological order is obliged to use. This coal is sometimes worked in the smallest possible way, by benching upon its outcrops. It has in no case been reported more than 2 feet in thickness. It is shown on Sections 14, 23 and 35.

The coals that are mined in the township are the following, viz.: the Lower Kittanning, No. 5, and the Middle Kittanning No. 6. The Lower Freeport coal, No. 6*a*, is present in a few sections, having a thickness of 18 inches. These seams are respectively known as the Lower, Middle, and Upper seams.

The Lower Kittanning seam, which is here styled the "lower vein", is mined on Sections 23 and 26, on the farms of John Studer (formerly the Hitchcock farm) and F. Dumolt, respectively.

On the Studer farm, the coal has been quite largely mined for neighborhood use in years past. The seam yields 42 inches of good coal in an undivided bed, overlain by 8 inches of bone coal. Nodules of pyrites are distributed through it. The coal burns with a strong heat, but with less flame than the coal above it. It is hard and bright, and finds ready sale when mined. The Dumolt coal is not as thick as the Studer coal. It is not probable that these developments will ever warrant any considerable mining enterprises, as the seam shows itself unsteady in this immediate neighborhood, running down to 10 inches, or even less.

The Middle Kittanning coal, which happens to be known here as the "middle vein", is, as usual, regular and persistent.

An approximate estimate of its acreage in the township was made, by taking the aggregate of what the landowners claim. Their figures give 2280 acres, an area which is probably not greatly in excess of the facts. It occupies Sections 13, 14, 23, 24, 25, 26, 27, 34, 35 and 36, in part or in whole. The seam shows its northern phases throughout most of the township, in all respects, being but 3 feet thick, being overlain with 1 to 2 feet of bone coal, being moderately cementing, burning with a purple ash and being high in sulphur. In parts of the township, however, change begins to show in these features. The coal becomes more open-burning and the color of the ash is less pronounced.

The chief mines in this seam are in Sections 13, 24, 25, 26, 35 and 36. A number of country banks are kept open here for the township supply. The coal is uniformly 3 feet thick, and everywhere carries the "bone" above it, but in Sections 13 and 24 it becomes somewhat slaty and inferior in quality, evidently marking the outer margin of the original swamp.

The seam will yield in portions of this area a fair basis for shipping mines, as has already been demonstrated in the Bristol and McCuneville mines, whenever lines of transportation are provided.

The coals of the northern portion of Monday Creek township, viz., in Sections 1, 2, 3 and 4, agree in all respects with the coals already described from Jackson township. In quality and thickness and structure, the Middle Kittanning coal is identical with the phases of the seam last described. It is here known as the "three-foot seam", while the Lower Kittanning is styled the "two-foot seam".

The general section of this neighborhood is well represented in a

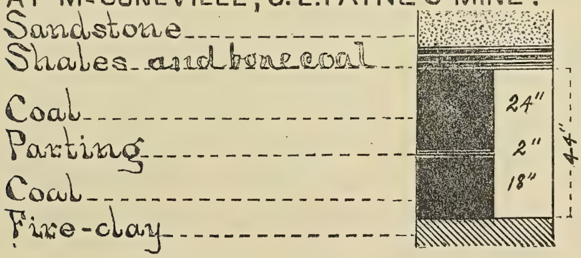
skeleton section taken on the farm of Horace Wilson, Section 3, Monday Creek township. Some of the intervals are in excess of the usual measurements. The section is as follows:

Middle Kittanning coal, No. 6, "Three-foot seam"—
  Interval—Shales—24 feet.
Lower Kittanning coal, No. 5, "Two-foot seam"—
  Interval—11 feet.
Baird ore, Ferriferous limestone 8–10 inches—
  Interval—70 feet.
 (Containing Tionesta coal, No. 3*b*, not shown here.)
Upper Mercer limestone, 15 inches.
 " " Coal, { Cannel—16 inches. Coal—20 inches.
  Interval—45 feet.
Lower Mercer limestone, in two benches, separated by 3 feet of clay.
  Interval—12 feet.
Union Furnace block ore.

It is in sections adjoining those last referred to that the Middle Kittanning coal makes its great increase in thickness and becomes a part of the Hocking Valley field proper. This change is always an abrupt one, and is confined to the upper portion of the seam almost exclusively. It will be discussed in the next chapter.

The coal of northern Salt Lick township holds the same relation to the "Great Seam" as the coal last described. The boundary between the low and the high coal passes through Sections 12, 11, 15, 16 and 17, and all the coal mined in the seam north of this boundary belongs to the northern phase of the seam, except that its ash is lighter colored and that it is less cementing in character. Coal of this type is mined largely in Sections 5, 6 and 8. The structure of the seam in J. E. Payne's mine at McCuneville is as follows:

FIGURE LXXXI
STRUCTURE OF MIDDLE KITTANNING COAL (No. 6)
AT McCUNEVILLE, J. E. PAYNE'S MINE.



This represents the mines between this point and Bristol Station. The section of the coal at Bristol has been given on a preceding page.

A small basin of the Lower Kittanning coal is indicated in the vicinity of McCuneville. The seam crops out in the roadway, 1 mile north of McCuneville, on the Lexington road.

Space does not allow a fuller discussion of the coals of this field. Enough has been given to serve as a guide in mining enterprises that may be undertaken here.

COAL MINES OF LICKING COUNTY.

But few words are required to describe the coal mines of Licking county. The geological range of Hopewell and Franklin townships is sufficient to afford a mining field, but the coals themselves are mainly wanting. The series rises above the place of the Kittanning coals, throughout part of the territory occupied by Flint Ridge, but of the 8 seams that are due in the interval between the Freeport horizon and the base of the Coal Measures, only two are ever opened, and neither of these is persistently mined. The two seams referred to are (1) a lower coal, which is probably the Sharon, and (2) the Lower Mercer coal. The first is a thin and uncertain seam that has nowhere been followed far under cover, and that does not seem likely to be worked on any larger scale. Not an active coal bank is now known in the seam in the county.

The Flint Ridge Cannel.

The second seam, viz., the Lower Mercer coal, has much more importance and reputation, and in it the only mines of the county that deserve the name are opened. The chief interest is in connection with the cannel phase of the seam underneath the western extremity of Flint Ridge.

A promising body of cannel coal has long been known and long been worked, though irregularly, in the western part of Hopewell township (mainly in lot 33), under the name of the Flint Ridge cannel. It has been noticed and described in all of the geological reports that have been made upon the region for the last 50 years, and many mining schemes have been founded upon it, but none of them have been largely successful. The lack of transportation has always blocked the way, let alone all other considerations.

Flint Ridge has always been counted one of the most anomalous and at the same time one of the most interesting formations in Ohio. Its approximate areas, for it consists of more than one outlier, are laid down upon map No. 5, being here represented for the first time. Though the boundaries are laid down distinctly on the map, the lettering is quite obscure, but the Ridge can be recognized as constituting the only shaded areas in Hopewell township of Licking, and also in Hopewell township of Muskingum county. By an inspection of the map it will be seen that the Ridge is a remnant left from long continued erosion. That large areas of the formation have been removed is attested by the enormous quantities of flint that cover the slopes, as well as by the situation of the remaining masses of the Ridge. The flint appears to belong to the Ferriferous limestone horizon. The thickness of the sheet it is hard to determine, as there are few distinct sections of it to be found, but most of it would probably keep within an outside limit of 10 feet.

The cannel horizon lies about 100 feet below the flint. The section including it is about as follows:

Lower Mercer limestone	5 ft.	
Coal, bituminous		4 to 6 inches.
Clay, sandy	2 ft.	
Cannel and bone coal		6 to 8 inches.
Clay	1 ft.	
Cannel seam	3 to 4 ft.	
Black slate, floor of mine		4 inches.
Slate	2 ft.	
Coal, bituminous, reported	1 ft.	
Fire-clay.		

The coal is opened near the western boundary of the basin. The land is high enough to hold the seam for several miles to the westward, but there are no indications of its presence.

In fact, in the westernmost entries of the present mines, the coal seemed to come to an abrupt termination. The field extends to the east and south, but just how far there has not been exploration enough to determine. The probabilities are in favor of a considerable tract. Some of the parties best acquainted with the territory estimate the productive area to be not less than 1000 acres. A shaft sunk $\frac{1}{4}$ mile east of the present mines found 3 feet of good cannel. Two miles to the eastward of the mines, Capt. John M. Loughman reports 2 feet 8 inches

of cannel. On the farm owned by Mrs. Snelling, one mile to the southeast of the mines, the cannel is 2 feet thick, but a mile further, on Leonard Cook's land, it has run down to 8 inches.

The coal is fairly steady in all of the present workings of the mine. It nowhere falls below 3 feet, and it rises above 4 feet only in the main swamps of the seam. It probably averages $3\frac{1}{2}$ feet. The roof occasionally makes trouble, clay slips letting down everything to the limestone. Posts are set about 3 feet apart in the rooms. The floor is somewhat irregular, rolling so much as to interrupt drainage to some extent, and confusing the normal dip. There is nothing in this, however, to obstruct any systematic or continuous workings, if such shall at any time be established here.

Quite a large acreage has been worked out in the 50 years in which the coal has been mined, but no one is able to say just how much. The miners who know most about the workings put the estimate of the exhausted area as high as ten acres. Counting in the coal that has been passed by, and so lost, it is possible that as much as ten acres have been overrun. There is still abundant opportunity to drive entries in upon solid coal.

The seam is mined by bearing in at the top and then by blasting where opportunity offers. One keg of powder brings about 50 tons of coal. A miner must work hard to get out 2 tons per day. The price of mining is about $1.00 per ton. A royalty is paid of 40 cents per ton. The coal is mainly sold for neighborhood use, a large territory around finding in this mine the only home supply. The coal is used in stoves as well as in grates, and with equal acceptance.

More or less coal is sent out by rail every year to the neighboring towns, and a little has been carried to distant markets, as Washington, Baltimore and New York. It is or has been used in the gas-works of Newark, Delaware, Sandusky, Dayton and Columbus. The long haul (4 miles) to the railroad is expensive, making the coal cost $2.75 to $3.00, on board the cars. The coal sells at the bank's mouth at $1.80.

The cannel was formerly turned to account for coal oil distillation, quite an expensive plant being established here before the development of Pennsylvania petroleum.

As to the character of the cannel, it is to be regretted that no new statements can be made. It runs rather high in ash and the character of the product is often damaged by the miner's sending out a 2-inch

"bone" at the bottom of the seam that ought not to be sold as coal. Furthermore, at the top of the seam, there is a long-grained and slaty band that ought to be rejected, but which sometimes finds its way into the coal. Throughout the body of the seam, there is but little difference in quality. The cannel is curly and excellent in appearance. It ignites easily and burns away completely into ash, the volume of which is, however, large, as has been already stated.

Authentic statements are wanting as to the output of the mines. The annual production probably exceeds 2000 tons. The mines are in bad shape, the ownership and management having been often changed, and each owner and lessee desiring to secure as much coal as possible at the smallest outlay. Ventilation is accidental and therefore defective, and the drainage is also neglected. Whether a large enough market could be found to keep a railroad mine running, is a question for coal operators and railroad companies to settle, but if the area, when duly proved, is found to contain as much coal as present estimates cover, there is no question but that properly equipped and well-managed mines could be made to produce a steady and respectable output for many years. A home market can, in any case, be always counted on for several thousand tons of coal, annually. The fact that the coal bears storing like quarry rock enables the miner to work regularly and continuously. This coal does not deteriorate by being got out in advance of the demand.

Very different estimates have been placed upon the value of this field at different times in its history. When sold under the Sheriff's hammer, it is said that the price realized for it was only about one-twentieth of the amount offered for it and refused a few years before. It is now possible by judicious and not expensive investigation to determine its real value.

CHAPTER XVI.

THE COAL SEAMS OF THE LOWER COAL MEASURES OF OHIO—CONTINUED.

THE HOCKING VALLEY COAL FIELD.

BY EDWARD ORTON.

The Hocking Valley coal field will be considered in this chapter as comprising those portions of Perry, Hocking and Athens counties in which the Middle Kittanning coal (Coal No. 6, of Newberry) reaches or exceeds 5 feet in thickness. Almost all of this territory is included within the drainage limits of the Hocking river, and this fact determines the name by which the field is known. For the sake of convenience, a few small districts will be described in this chapter in which the coal of the Middle Kittanning seam falls below 5 feet. These districts embrace portions of York and Waterloo townships, Athens county, and portions of Starr and Washington townships, Hocking county.

The field, as thus qualified, embraces the southern part of Monday Creek township, the south-eastern half of Salt Lick, the southernmost sections of Pleasant and Coal and Monroe townships, in Perry county; in Hocking county, Ward, Green and Starr townships, with a small and unimportant outlier in Washington township; in Athens county, Trimble, Dover, York and Waterloo townships.

Some general statements as to the character and structure of this field are given in Chapter I, pages 102—117.

The Hocking Valley produced in 1883, 3,270,000 tons of coal, or about $\frac{2}{5}$ of the total production of Ohio. This statement shows that it far transcends in present importance any other single coal field of the State, being fairly comparable with all the rest combined.

Map of the Coal Field.

A map accompanies this chapter, in which the Hocking Valley field is shown, together with some contiguous territory. The areas occupied by the Middle Kittanning seam in this district are laid down, and that portion of the seam which is 5 feet or more in thickness, and which by the definition here given constitutes the Hocking Valley field, is separately distinguished. The outer margin of the Lower Mercer limestone and the boundary of the coal measures are also laid down upon the map. These last outlines agree closely with each other in some parts of the field.

The most important feature of the map is the representation of the areas of thick coal. A few statements will here be in place as to the methods employed and the principles recognized in assigning the boundaries of these areas.

On the north-west and west, the outcrop of the seam is easily followed, and here, therefore, comparatively little difficulty is found in laying down the boundary. The line was not, however, instrumentally determined for this part of the field, but was fixed by reference to farm and section lines and to roads and streams, the scale of the map, viz., 2 miles = 1 inch, not demanding nor rewarding minute accuracy.

From Shawnee eastward, the boundary between the thick and the thin coal of the seam lies mainly under heavy cover, and for its location we are dependent upon the information gained from mines and drill holes. There are often reasons why those who have expended money in drilling do not choose to make public the knowledge that they have gained. There may, therefore, be facts in the possession of some parties, with which the boundary, as here laid down, will not exactly match. All, however, agree that the transition from thick coal to thin is abruptly made, and it is believed that future development will not greatly change the line as here given. Many of the facts used in determining this boundary were furnished by Col. James Taylor, of New Lexington, and Messrs. Black, of Buchtel, and Corcoran, of Corning, but these gentlemen are not made responsible for the boundary as here laid down.

The boundary between 5-feet coal and thinner coal in the south-west corner of York township and in the south-east corner of Starr township, is not as definite as could be desired. There is a more

gradual reduction of the seam here than on the northern boundary. Much of it is under cover, and in the outcropping portion but little mining has been done, so that the opportunities for observation are few and unsatisfactory. In several of the eastern and southern sections of Starr township, more than 5 feet of coal is claimed, and the claim is recognized upon the map, but in any case the area of thicker coal cannot be large. The Carbondale mines have been driven a long ways in this direction, and all of their entries show less than 5 feet of coal, the average, indeed, not exceeding 4 feet.

In Sections 23 and 29, Brown township, Vinton county, coal measuring more than five feet is found at one or two openings of this seam, but nowhere else in the township is it known to yield even 4 feet of coal. A small area is credited with 5 feet coal in these sections.

The continuity of the coal is inferred and is indicated upon the map for all areas upon the several sides of which the seam is found, either in outcrops or in shafts and drill holes. When, for example, the seam goes under cover in the direction of its dip and is found again as soon as its proper level is reached in the valleys to the south and east of the first-named outcrop, the whole intervening territory is represented as possessing the seam, unless there are known facts to the contrary.

The final disappearance of the seam to the south and east is indicated upon the map by broken lines, but so far as its presence has been fully demonstrated by trial pits or by working shafts, it is not so designated.

Where the seam descends in good volume and condition beneath its final cover, some extension of it in the direction of its descent must be inferred, but recent developments, especially in Monroe township, lead to the opinion that its entire eastern boundary is likely to prove abrupt.

It is to be distinctly understood, that no claim is made that all of the territory marked as possessing the thick coal has been adequately proved. In those portions of the field most fully tested by mining, or by drilling, many breaks in the continuity of the seam have been found. The coal is reduced or irregular in thickness, or is entirely wanting. Where such "wants" or irregularities are known, the fact is noted upon the map by broken lines, but exploration has not advanced far enough as yet to make it safe to lay down the boundaries of these

"wants". A cloud is thrown upon a section or farm if, upon trial, the coal is found deficient or faulty. This question as to the state of the coal is expressed upon the map by the broken lines, but there is no doubt that in many cases bodies of good coal will be found in this broken territory. The text will treat of these several interruptions as far as they have been made known.

Attention must also be called to the fact that the townships most thoroughly tested are those most scarred, upon the map, by signs of deficient coal. That the coal lines of certain other townships are unbroken is due, without doubt, to our want of knowledge of the field. Wants and reductions will undoubtedly be found as soon as development begins.

No account of exhausted areas is taken in the representation of the coal. A considerable acreage has already been worked out in the most valuable part of the field, but the boundaries on the map are designed to indicate the original outcrop.

Previous Geological Reports upon the Hocking Valley Field.

The earliest methodical and detailed account of the geology of the Hocking Valley is to be found in the Report of Progress of the State Geological Survey for 1869. This important field was there made the subject of an excellent and widely distributed report by the late Professor E. B. Andrews, within whose geological district it was included. Its main coal seam was traced by him to New Lexington, on the east, where it was identified with the Upper New Lexington coal, and to Carbondale, on the south, where it was shown to be the coal mined in the large way for the Marietta and Cincinnati Railway Company. The establishment of these connections was a very important service to the geology of the Coal Measures of Ohio.

Many facts pertaining to the stratigraphical order of the field were also published, and the elements of a general section were accumulated. The economic geology of the coal and ore also received special attention. By Professor Wormley's analyses, the excellent character of the main Hocking Valley seam was fully accredited from a chemical point of view, while the rapid development of mining that was going forward along the newly-built lines of the Columbus and Hocking Valley Railway, and the successful establishment of blast furnaces in the district,

gave a practical guarantee of the validity of the claims that were made for it.

From this time forward, our knowledge of its geology was rapidly enlarged. Stimulated by a desire to secure as much as possible of the great mineral wealth of the Valley, companies and individuals vied with each other in acquiring, in all available ways, a knowledge of its real resources. Geological examinations made for these companies by Whittlesey, Andrews and Read, and published as private reports, extended our acquaintance with the field, while many local geologists and explorers worked up with care and skill the sections of their own immediate neighborhoods. At a somewhat later date, May, 1874, a report upon the field was prepared for eastern capitalists, by Dr. T. Sterry Hunt, of Montreal, Canada, which embodied the general facts of the geology as then understood, together with a number of valuable, original analyses of the minerals of the Valley.

In 1878, Volume III, Geology of Ohio, was issued. It contained a somewhat extended report, by M. C. Read, Esq., on the Hocking Valley Coal Field, a supplemental report, by Professor E. B. Andrews, on Perry county and portions of Hocking and Athens counties, or in other words, upon the Hocking Valley field, and also a supplemental report on the Hanging Rock District, in which the geological connections between the Hocking Valley and the Hanging Rock district were discussed at some length.

In 1881, Dr. Hunt published a second and much more complete review of the "Mineral Resources of the Hocking Valley." In it, he incorporated a great number of facts that had been brought out and established in the various reports already named, and he added many observations, measurements and analyses of his own, making the report on the whole a more complete account of the Hocking Valley than any that had previously appeared, but it would require more or less qualification in order to match with the facts as at present found.

The progress of our knowledge has shown errors of observation and interpretation in all of these statements, and there are still differences of view as to many questions pertaining to the geology of the district, but while each year adds to our knowledge facts which could be gained only by the practical development of the field, it also gives increased assurance to our interpretations of the general order, and although there is still much to be learned, there is already, in our pos-

session, a great body of well authenticated facts and well-grounded conclusions in regard to the field. These facts and conclusions it is the purpose of the present chapter to embody.

The practical development that is now going forward under the management of the large corporations that own so much of the field is of the greatest value. The Columbus and Hocking Coal and Iron Company, and the Ohio Central Coal Company in particular, are making very thorough and methodical examinations and measurements of their respective properties.

Acreage of the Hocking Valley Field.

Various estimates have been made of the areas that contain the thick coal of the Hocking Valley. Read estimates the field to be equal to 100,000 acres of 10 feet coal (Vol. III, p. 648). Hunt assigns an area of about 250 square miles or 160,000 to the field, without specifying the thickness of the coal contained. The map that accompanies this report is the first, so far as known, that has represented the areas actually occupied by the coal. Until such a map is in hand, only estimates and rough approximations of areas are possible, but with the map in hand, so many qualifications must be entered as to forbid the immediate attainment of any great degree of exactness. How far, for example, shall the coal be counted beyond its final disappearance below drainage? As has been said before, when the seam descends in full volume and in good condition below the valleys, *some* extension of it under cover must be recognized. The most important questions of this sort pertain to the Sunday Creek Valley, but the southern portion of the Hocking Valley presents problems of the same character. Again, it is difficult to measure with accuracy the many small outliers of the coal, but it is "the wants" of the seam that furnish the largest element of uncertainty.

The explorations so far made serve to mark the Sunday Creek Valley as the approximate boundary of the great seam. On the east side of the valley, the coal has been found faulty as a general thing, where it is not almost or altogether wanting, but there are areas in which it is known to be in normal character here, and to these attention will subsequently be called.

Counting the Ohio Central Railway as the eastern boundary of the thick coal, and the north line of Athens township as the southern

boundary, and balancing the many faulty regions within the field against the known extensions of the seam beyond the limits taken, we find the areas of the coal, 5 feet and upwards in thickness, to make an aggregate of 94,156.8 acres or 147.12 square miles.* Some reduction from these figures will be required in accounting for the coal already mined in the Valley, but the facts bearing upon this important question will be better appreciated after the survey of the several subdivisions of the field, and this topic will accordingly be taken up in a subsequent part of this chapter.

In addition to the coal of the great seam, there are several other sources of coal supply within the district. The Lower Kittanning coal is occasionally mined on a small scale, as is also the Lower Freeport seam, while the Upper Freeport coal here becomes the basis of large mining operations. It is the only seam of the three that makes a really important contribution to the coal resources of this region, and there are large areas in which it would, of itself, furnish a proper basis for extensive work.

General Section of the Field.

The geological range of the Hocking Valley field is shown in the appended section. It will be seen from this that it extends from the Mercer horizon to the Crinoidal or Ames limestone. In the high ridge of Trimble township, between Snow Fork and Sunday Creek, the strata rise at least 100 feet above the Crinoidal limestone, or nearly to the place of the Pittsburgh coal, but these upper strata include no valuable or easily recognized elements, and they occupy a comparatively small area, and need not therefore be counted in the geological column. The Crinoidal limestone is reached in only a small territory, and very rarely in the same hills that cover the Middle Kittanning coal.

The column is as follows:

Crinoidal limestone—Ames, of Andrews	5	feet.
Interval, mainly shales, red and drab, carrying nodules of hematite at one or more horizons	45	"
Ewing limestone, nodular and uncertain. Often replaced by iron ore	0– 3	"
Interval, mainly shales	40	"
Cambridge limestone, frequently doubled (Sometimes bears iron ore, "black limestone")	2–10	"

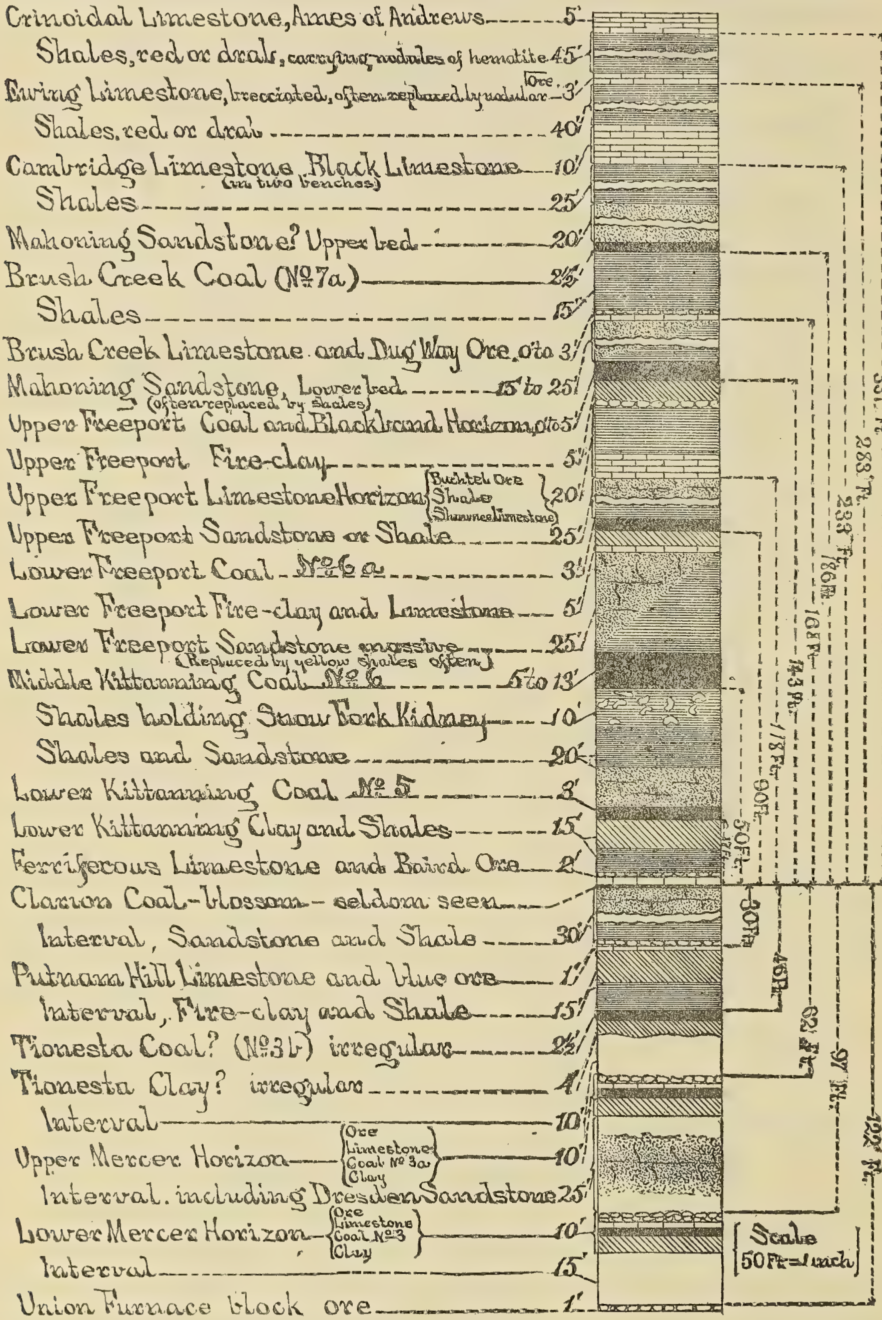
*The method used in determining the acreage consisted in cutting out an accurate map of the field including outliers, in weighing the map, and in computing its area by comparison with the weight of a standard area.

Interval, containing shales and a coarse Sometimes conglomeritic sandstone Upper division of Mahoning sandstone	50	"
Brush Creek coal (No. 7*a*)	0– 2½	"
Interval	10–20	"
Brush Creek limestone, often replaced by ore Dug-way ore	0– 4	"
Mahoning sandstone, lower bench Coarse and sometimes conglomeritic Sometimes replaced by shales	15–25	"
Upper Freeport coal and Blackband horizon	0–10	"
Coal No. 7—		
Upper Freeport clay and shale	2–10	"
Upper Freeport limestone horizon. { Buchtel ore 5 ft. Shales 12 ft. Shawnee or buff limestone 3 ft. }	15–20	"
Interval, Upper Freeport sandstone or shale	10–20	"
Lower Freeport coal (Nos. 6*a* and 6*b* of Vol. III)	0– 3	"
Lower Freeport limestone, lower buff (Norris and Snow Fork limestones of Vol. III) Kiney ore	0– 2	"
Lower Freeport sandstone, often replaced in whole or in part by yellow shales	30–40	"
Middle Kittanning coal, No. 6	5–13	"
Shales containing Snow Fork Kidney ore	2–10	"
Interval, sandy shale, mainly	10–20	"
Lower Kittanning coal	1– 3	"
Kittanning clay and shales	10–20	"
Ferriferous limestone and Baird ore	1– 4	"
Clarion coal, blossom occasionally seen—		
Interval, sometimes sandstone, generally shale	20–30	"
Putnam Hill limestone, generally represented by blue ore	0– 1	"
Interval	10–15	"
Tionesta coal? Coal No. III*b*	0– 2½	"
Tionesta clay?	0– 5	"
Interval	10	"
Upper Mercer horizon. { Ore. Limestone. Coal. Clay. }	1–10	"
Interval, including Dresden sandstone	20–30	"
Lower Mercer horizon. { Ore 0– 1 ft. Limestone 2–10 ft. Coal 0– 6 ft. Clay 2– 5 ft. Interval 10–12 ft. Lower ore 0– 1½ ft. }	———	

The facts are represented in the accompanying figure :

FIGURE XC

GENERAL SECTION OF THE HOCKING VALLEY COAL FIELD.



The elements that are counted valuable in the series are named in the preceding table. There are some horizons at which fire-clay and sandstone may perhaps be worked to advantage that are not named in this column, but the coals, limestones and ores that have been proved to be of economic value all find place. A few years ago, the view was held by some geologists and also by practical investigators in the field that valuable beds of iron ore occur in the Barren Measures of this region, and especially in that part of them included between the Upper Freeport coal and the Ames limestone, and quite a system of ores, aggregating many feet in thickness, was introduced into the upper portion of the Hocking Valley column, but inasmuch as the stimulus to ore production occasioned by the establishment of the new blast furnaces of the valley has failed to develop any permanent supply at a single one of these horizons, it is safe to conclude that these so-called ores have no economic value. Their instability as geological elements and their poverty in iron forbid them to be counted as elements of mineral wealth. There are nuggets of hematite scattered through the red clays that are rich in iron, but they have nowhere yet been found in the field or in the State in accumulations that would repay mining.

Structure of the Seam.

In structure, the Hocking Valley coal always has the three benches of the normal Middle Kittanning seam, with some addition of its own. In other words, the Great Vein consists of the normal, three-bench seam of Middle Kittanning age, covered and reinforced by a Hocking Valley supplementary seam, the latter consisting of one or two or more benches. The supplementary seam is separated from the original seam by a thin shale parting, which is often disregarded in mining, but which is for the most part distinctly recognizable when looked for. The supplementary seam belongs to a later period of the Middle Kittanning age. In other words, there were conditions in the Hocking Valley portion of the Middle Kittanning coal-marsh under which the growth of the coal went on in the interior after it had been arrested on the margin. A slight warping of this portion of the marsh, by which a few scores of square miles were converted into a low island, would seem to supply the necessary conditions.

There is no foundation whatever for the theory which accounts for the thickness of the "Great Vein" by the coalescence with the normal

Middle Kittanning seam of one or both of the Freeport coals (Nos. 6*a* and 7). There are numerous localities in which *both of the latter seams appear in the same vertical section with the great seam*; also, the character of the Freeport coals is quite different from that of the top coal of the Hocking Valley seam.

The lower bench of the normal seam ranges from 6 to 30 inches in thickness. In the western part of the field it is thinnest; it attains its greatest thickness in the Sunday Creek Valley. The lower slate or parting, which makes the upper boundary, is seldom more than 1 inch in thickness, and ½-inch is the common measure.

The middle bench of the normal seam ranges from 4 to 28 inches in thickness. It is thinnest in the Sunday Creek Valley, and thickest in the Straitsville and Monday Creek regions. The second slate, which covers the second bench of coal, is very steady and regular. In fact, it is very nigh coextensive with the Middle Kittanning seam. In thickness it ranges between 2 and 4 inches.

The third or upper bench of the normal seam, which is from 12 to 24 inches in thickness, is generally poor in quality, at least for part of its volume. It holds this character almost everywhere, through Muskingum and northern Perry, where the seam is single, being known as "bone coal," and very seldom being taken down as fuel. Directly above the second slate there is always throughout the Hocking Valley field a band of inferior coal. It is known as bone coal, hard bone, soft bone and soft coal, and the miner is almost everywhere instructed to reject it. Occasionally it becomes marketable, both in and out of the Hocking Valley. Very often, after rejecting 4 to 8 inches of soft coal at the bottom of this bench, a good piece of coal is found above. This bench is of the best character in the Straitsville and Monday Creek districts.

The supplementary seam of the Hocking Valley is, in the general view, counted with the upper bench of the normal seam, the whole being known as top coal. It has a maximum thickness of 10 feet. All the thickness of the Hocking Valley seam in excess of 6 feet, and in many parts of the field all in excess of 4½ feet, is to be credited to the supplementary seam. Its value is small in proportion to its volume. In the Sunday Creek Valley, where it reaches its maximum, it has been found impossible to market more than 3½ feet of the 10 that belong to it. Its coal could scarcely sustain itself in market if separated from

the lower benches of the normal seam. It is always open-burning and low in sulphur, but it inclines to excess of ash. It mines large, and has great strength to bear transportation and handling.

There are numerous irregular partings in this top coal when it becomes thick, only one of which is widely extended and measurably regular. A four-inch black slate, known as the third slate, and charged with sigillaria impressions, is found 8 to 9 feet above the bottom of the Great Vein, everywhere throughout Monroe township, in the Sunday Creek Valley. As it now appears, it is the same horizon at which a constant layer of cannel or horn coal is found throughout the western portions of the Great Vein. The coal above the slate becomes a rider seam. It runs too high in ash in most of the field where it occurs to be fairly marketable. It reaches a maximum thickness of 4 feet, but most of it is left in the mines.

Character and Composition of the Hocking Valley Coal.

The character of the coal throughout the field is fairly uniform. Taken as whole, it is an open-burning coal of pronounced character, but the lower bench, burned by itself, is somewhat cementing. It is distinctly laminated and holds a moderate proportion of mineral charcoal. It ignites easily, swells slightly in burning, and leaves a white or gray ash. It is well approved for steam generation, and also for rolling mill fuel. To household use it is admirably adapted, rivaling in this line of service the block coals of the Mahoning and Tuscarawas Valleys. The most important single use to which it is put is iron-making. The successful experience of the blast furnaces that have been built in the valley within the last ten or 12 years, and that have made the Hocking Valley coal their chief and often their sole reliance for fuel, leaves no open questions in regard to its adaptations to this important service. As a furnace coal, it is not surpassed in the State, and scarcely by any known bituminous coal. It is also used to a small extent in gas-making.

In chemical composition, the average of 10 mines, including several of the best of the field, the mines being located at Shawnee, and from there westward as far as Nelsonville, is as follows:

Average of Ten Mines of the Hocking Valley (Lord).

Moisture	5.93
Volatile combustible matter	36.48
Fixed carbon	52.41
Ash	5.13
Total	100.00
Sulphur	1.09

The best showing from any one of these mines and also the poorest results from any one mine are given below, Nos. 1 and 2:

	1.	2.
Moisture	6.61	5.38
Volatile combustible matter	36.40	37.58
Fixed carbon	54.17	51.21
Ash	2.81	5.83
Total	99.99	100.00
Sulphur	.51	1.94

While there is something to choose between the products of these two mines, the figures show scarcely wider differences than we ought to expect from different rooms of the same mine.

The range of the several elements in these 10 mines is also shown below:

Moisture	5.26	to	7.09%
Volatile combustible matter	35.61	to	37.58%
Fixed carbon	50.92	to	54.59%
Ash	2.81	to	6.86%
Sulphur	0.516	to	1.94%

These figures evidently show one of the very best coals of the State, and beyond question the steadiest in composition of any of the large fields. When it is remembered that each analysis represents all of the seam that is sent out by the miner, just as it is found in the mine from which it is taken, as far as this can be provided for by careful and thorough sampling, it will be seen that the average above given actually and accurately represents the lump coal that is sent out from the central and western portions of the Hocking Valley field.

In strength and ability to bear handling, the coal is somewhat

unequal, but the product of the entire field ranks high. The coal of Sunday Creek, Shawnee and Straitsville, when skillfully mined, is scarcely surpassed in strength by the famous block coal of the Mahoning Valley. While other portions of the field fall below this standard to a certain extent, the coal that they furnish is at least equal in strength to any other Ohio coal.

The coal is everywhere mined by undercutting and blasting. The "bearing in" is done in the bottom bench of the seam, which is the best part of the coal in several respects. The cost of powder ranges between 3 and 4 cents per ton of coal.

The coal is universally prepared for market by screening. The standard that is generally recognized for the screens is 12x6 feet, with $1\frac{1}{4}$ inches between bars. The bars are either steel or iron, and are generally $\frac{1}{2}$-inch to $\frac{3}{4}$-inch wide on the upper surface.

One-third of the coal sent out by the miner passes through a screen of these dimensions. Of this third, somewhat less than half is slack, which has hitherto been mainly lost. The balance is unequally divided between nut and pea coal, when the latter grade is made. If the pea coal is not separated, the slack is increased to this extent. The nut coal is counted about half the value of the lump coal at the mine. The pea coal does little more than pay for handling. Reduced to percentages, the several grades appear as follows:

Lump coal	66%	
Nut coal	10 to 20%	33%
Pea coal	5 to 15%	
Slack	9 to 25%	

By recently introduced elevators, the Ohio Central Coal Company has brought down the percentage of slack to between 9 and 10 per cent. of what the miner sends out.

The extreme regularity of the coal, the excellent roof that covers it, the fact that the mines are, in so large a part of the field, level free or hill mines, all these facts reduce the demand for skill in mining to somewhat lower terms than elsewhere. At least, mining can be done here with a smaller amount of training and experience than in many districts.

The summer mining rate at present is 70 cents per ton, and the winter rate 80 cents. With full working days, the miner will be paid better at these rates than elsewhere in the State, his daily earnings ranging from \$3.00 to \$5.00, and sometimes rising to \$7.00 or \$8.00, but,

for various reasons, the working days are so few and far between, that the yearly earnings of the miners in this field fall below the yearly earnings of many that are mining in thin seams. In short, the natural advantages of the field are lost in a great degree, so far as labor is concerned.

The several divisions of the Hocking Valley field will now be briefly described. The main divisions are as follows:

1. The Sunday Creek Valley.
2. The Shawnee and Straitsville district.
3. The Monday Creek Valley.
4. The Hocking Valley proper.

To these main centers, the smaller outlying fields will be attached, as convenience dictates.

1. The Sunday Creek Valley.

This is the first division of the Hocking Valley coal field that is entered in coming from the eastward. It is the largest of the several divisions just announced, comprising fully one-half of the entire acreage of the field. To it there belongs the southern tier of sections of Pleasant, the whole of Monroe, eight to ten sections on the eastern side of Salt Lick and Coal, and the whole of Trimble and Dover, with the exception of the westernmost line of sections in each. It is the latest in order of development of the several divisions of the field, an outlet for its coal being first afforded in 1880 by the construction of the Ohio Central Railway. The railway company purchased about 12,000 acres of coal land and began the work of mining and shipping at the date above named, on a very large scale.

The Sunday Creek Valley holds two workable seams of coal, viz., the Middle Kittanning, No. 6, and the Upper Freeport, No. 7, which is also known as the Bayley's Run seam.

The first of these seams, known generally as the "Great Vein", attains in this district the largest measure of any coal seam in the State. On Section 18, Monroe, its entire thickness is 13 feet 2 inches, and on Section 23, Salt Lick, 14 feet, the partings of the seam being included. Through the chief mines of the district it measures about 11 feet.

Up to the time of the first real opening of the field in 1880, it was universally considered the most important and valuable half of

the entire deposit of thick coal. Lying mainly below drainage, the coal had escaped, for the most part, the accidents of modern erosion, and thus its acreage was greatly increased to the square mile, above the western districts. The analyses reported from the various openings seemed to show a coal of excellent character throughout; at least, they gave no hint that any considerable portions of the seam would need to be rejected. "Wants" in the coal had been revealed at several points, it is true, mainly in the central and southern parts of Monroe, and in some adjacent sections of Coal and Trimble townships, but no misgiving had been aroused as to the steadiness of the seam at large. When the Ohio Central Railway Company secured access to the field, the opening of the coal was carried forward in a very thorough manner, the plants for its several mines being by far the most elaborate and expensive that had thus far been introduced into the Hocking Valley field.

The development of the Sunday Creek Valley has now been going forward at a rapid rate for 3 years, and it must be confessed that its results have, to a great degree, proved unsatisfactory and disappointing. The unfavorable facts are of such a character that they could not well have been brought to light, except through the agency of practical development. The failure to recognize them at an earlier date does not therefore discredit the sagacity of the geologists who explored the field and who committed themselves unreservedly to the strongest statements as to its resources, nor does it reflect upon the judgment of the capitalists, who felt sure, in planting their millions here, that they would reap speedy and certain and generous returns.

Though a cloud has been thrown over the region by the failures alluded to, it is still true that the Sunday Creek Valley is one of the great coal fields of Ohio, and will continue to be so for scores of years to come. The Ohio Central Coal Company, in particular, has control of a large acreage extending towards Shawnee, and sharing the character of that field, in addition to a noble body of coal included in Sections 7, 8, 9 and 16, of Monroe township, as well as other valuable territory.

To understand the facts involved in the development of this field, it will be necessary to keep in mind the structure of the seam in the Upper Sunday Creek Valley, which is as follows:

4.	Roof coal or Rider seam	$2\frac{1}{2}$ to 4 ft.	
	Third slate—Roof of entries, etc		4 to 4 inches.
3.	Upper bench of coal { Top coal / Bone coal }	5 to 6 ft.	
	Second slate		2 to 4 inches.
2.	Middle bench of coal	5 to 5 in.	
	Lower slate		$\frac{1}{2}$ to $\frac{3}{4}$ inches.
1.	Bottom bench of coal	2 to $2\frac{1}{2}$ ft.	
	Fire clay.		

A peculiarity of the structure is the reduction of the middle bench to such small proportions, smaller than is elsewhere found in this seam, but the bottom coal has full thickness and unusual excellence by way of compensation.

When the field was opened, it was popularly supposed that the entire 10 to 14 feet of the seam was available for the market, but those who understood the other districts of the "Great Vein" best, made but little account of the rider seam, and accordingly it was no great disappointment to such, to learn what the market soon taught, that the $2\frac{1}{2}$ to 4 feet of this part of the seam must be left behind. The third slate in any case makes the safest roof under which to work, and the rider would not, therefore, ordinarily be taken until pillars were drawn. All of the coal below the third slate, aggregating 7 to 9 feet in thickness, was counted marketable, without a question, except that the upper portion was known to contain a layer of cannel or horn coal in places, and there was also known to be a suspicious band directly above the second slate.

The cannel was found in quite large development in several of the Sunday Creek mines, lying two feet below the third slate, and being from 10 to 15 inches in thickness. This required the splitting of the top coal and effected a reduction of $\frac{1}{8}$ of the thickness still counted available after the rejection of the roof coal.

The remaining seven feet of the seam went forward to market, but serious complaints at once came back on the part of those using the coal. Wherever hot and constant fires were to be kept up, it was found that the Sunday Creek coal proved unsatisfactory, not from the character of the whole product, but on account of about $\frac{1}{4}$ of what was sent out. It did not take a long time to trace this inferior portion back to its location in the seam. It was found in a justly suspected locality, i. e., directly above the second slate, and, as finally worked out, was

seen to consist of two portions, the lower one being a little more, and the upper one a little less, than a foot in thickness.

The lowermost received the designation of the "bone coal" or the "*hard* bone" by way of distinction. The upper portion was termed the "soft bone".

The designation "bone coal" as applied to these bands is not well chosen. They have no resemblance to cannel coal, as the term would seem to indicate, but the lower consists of thin sheets of bright or cherry coal, separated by much thicker layers of black shale or mineral charcoal. Upon fracture, the coal shows a peculiar crinkled appearance, which often is found, however, in connection with coal of good quality. No one would have a right to reject this band on account of its appearance, but when once learned, it can be easily distinguished. Its specific gravity is somewhat greater than that of good coal, and the crinkled appearance already named helps to mark it. The miner, however, can be under no doubt in regard to it on account of its position in the seam. It measures 12 to 15 inches in thickness.

The "soft bone" is a layer of impure and sulphurous coal, that crumbles and breaks badly on being handled. It lies directly above the hard bone, and has a thickness of 10 to 12 inches. It is often whitened in the seams by the formation of sulphates of iron and alumina.

The hard coal burns with a dull, dead fire, on account of the large amount of earthy matter that it carries, but when the two layers are burned together, a troublesome clinker, that runs on the grate, is formed. As soon as the character of the so-called bone coal was discovered, the miner was required to reject both benches, but a part of the "soft bone" is quite likely to find its way into the bank cars when it is not whitened with the sulphates named above. It mainly passes into slack before reaching market.

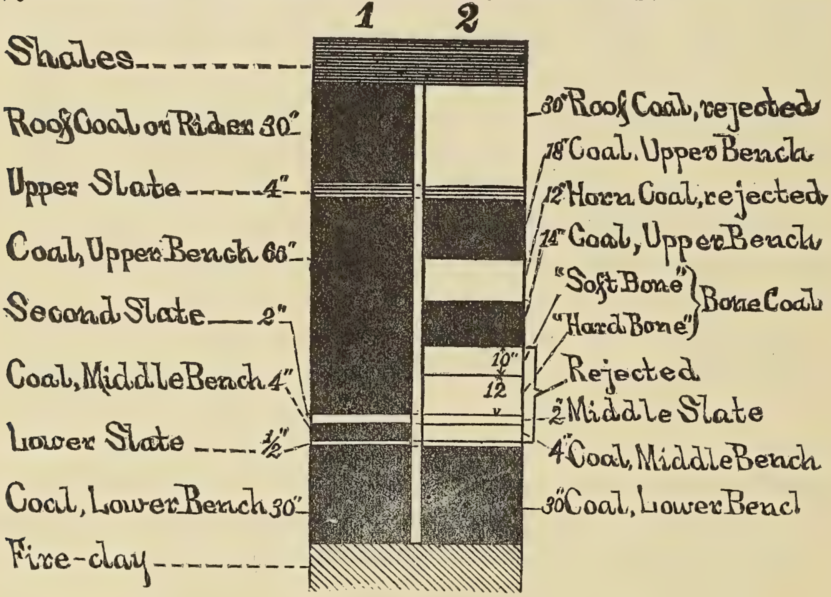
These two layers occasion a further reduction of the seam by the amount of 18 to 24 inches.

One other division of the coal it has been found necessary to reject, though not on account of quality. The middle bench has a thickness here of only 4 to 6 inches. Though the quality is good, the miner cannot justly be required under the present system of payment

for his labor, to use his time in splitting out this thin band, and accordingly the lower slate, or the top of the lower bench of coal, is made the line of division. Counting in the second or middle slate, the whole thickness of what is here rejected ranges from 2 to 2½ feet. In the accompanying diagram, Fig. XC*a*, the structure of the seam, as it was understood in 1880, is shown on one side, and on the other, the structure as it is found in 1883–4. Less than half of the coal, where it reaches its greatest thickness, is found to be first-class fuel, and to gain this amount the coal must be twice split.

FIGURE XCa

"GREAT VEIN" COAL OF UPPER SUNDAY CREEK VALLEY.
1 AS COUNTED BEFORE MINING WAS COMMENCED.
2 AS FOUND IN PRACTICAL WORKING.



A worked room of the mine presents a sorry spectacle, with its great ranks of rejected coal, much of which no one would dare to condemn from its appearance alone, and all of which is in reality better than some of the coals upon which large communities depend.

The Sunday Creek mines are now made to yield about 6,000 tons to the acre, which does not vary much from two-sevenths of the entire coal, where the seam reaches a thickness of 12 feet.

The reductions that are made on account of inferior quality result,

of course, in a decrease of quantity, but there is a more direct reduction of quantity from which half of the mines already opened have been found to suffer. The coal has proved unsteady, especially in the immediate vicinity of Corning. Clay veins come in, the coal grows hard and curly, the roof shales give place to sandstone, and the seam runs rapidly down to 4 ft., 3 ft., 2 ft., nothing. Mines, the expensive plant of which would have been good for a quarter of a century of use, have been already abandoned, and others that are still worked have but a short lease of life.

Three townships make up most of the Sunday Creek field, viz., Monroe, Trimble and Dover. Parts of Pleasant, Salt Lick and Coal are also included in it. The principal mining now going forward in this valley is in Monroe township.

Coal Mines of Monrce Township.

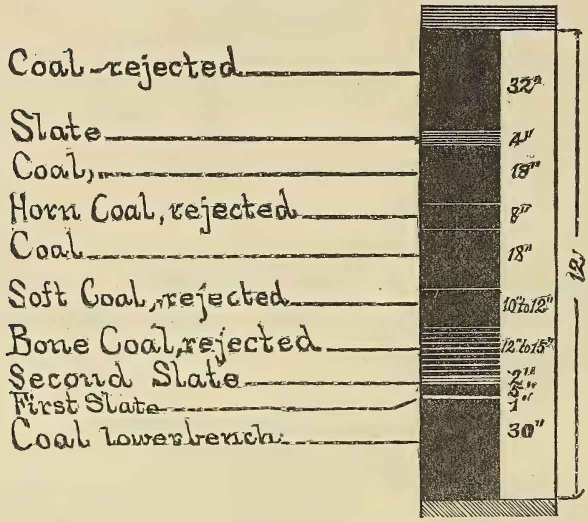
The mines of the Ohio Central Coal Company's lands in the Great Vein are designated by the odd numbers, 1, 3, etc., while for the mines in the Upper Freeport seam, the even numbers are used. Of the latter there are but two now in operation, viz., the twin mines of No. 12. Of the former, Nos. 3, 5, 7, 9, 11, 13, 15 and 19 have been opened and worked. Of these, Nos. 3, 11, 13, 15 and 19 are operated by the Ohio Central Coal Company; No. 7, by the Sunday Creek Coal Company, under lease from the Ohio Central Company, and Nos. 5 and 9, by W. P. Rend, also under lease from the Ohio Central Company.

All of these mines, except the last, are in reality opened in one body of coal. The entries of mines Nos. 3, 5 and 13 are already worked into each other. Nos. 9, 11 and 15 are situated on the east side of Sunday Creek, but their entries have been in some cases driven westward under the creek to the same body of coal referred to above. Nos. 3 and 5 are located in Section 9; Nos. 7 and 9, in Section 10; No. 11, in Section 15; No. 13, in Section 16, and No. 15, in Section 26. One description will apply to all where the coal is undisturbed.

Mine No. 13 will be treated more fully than the rest, as it exhibits best all the peculiarities of the field. It is entered by a shaft, 66 feet deep. That part of the coal extending to the north and west is regular and natural in all respects. The section of the seam is shown in the accompanying figure:

FIGURE XCI

STRUCTURE OF COAL AT MINE Nº 13, OHIO CENTRAL COAL COMPANY, CORNING.



The seam is divided in mining precisely as indicated in the right-hand side of Fig XC*a*, except that recently the "horn coal" has been reduced several inches by splitting off the bottom portion and sending it out as "splint coal," which now finds sale and acceptance in all markets. Between 5 and 6 feet of coal are now brought out.

The rooms of all the mines are worked 25 feet wide. Pillars and ribs are left 10 feet in width, and their strength thus far seems adequate to all demands. The coal is in all cases worked to the third main slate, which forms a roof of great strength and excellence. This slate is black, and contains an infinite number of sigillaria impressions. The coal below this slate measures 8 to 8½ feet in thickness. Posts are cut 8½ feet in length, and are set in the middle of the room, and the roads consequently lie along side of the ribs. This arrangement facilitates the drawing of the ribs, as all the refuse coal, the volume of which is very large, is stored in the middle of the room. Ribs are drawn early, so as to relieve the weight upon the entries. Whenever they are drawn, the rider seam is brought down to some extent.

Entries are driven in line with the cardinal points. This throws them a trifle off from the face and ends of the coal, but in working the coal, the miner secures the full advantage of the face by keeping one side of the room a little in advance of the other.

The composition of the Upper Sunday Creek coal, from the Corning and Rendville district, can be seen from the following analyses: The coal of mine No. 13 was sampled in a room from the portions of the seam sent out. The coal of Rend's mine, No. 5, was sampled in the same way. The coal of mine No. 3 was sampled from the bank cars. These mines all communicate with each other, and thus the three sets of samples may be counted as coming from different rooms of one mine.

Upper Sunday Creek Coal (Lord).

1. Mine No. 13, Corning, sampled from seam.
2. Mine No. 5, Rendville, sampled from seam.
3. Mine No. 3, Rendville, sampled from bank cars.

	1.	2.	3.
Moisture	6.11	5.29	5.70
Volatile combustible matter	37.99	38.32	37.80
Fixed carbon	50.59	50.77	49.22
Ash	5.31	5.62	7.28
Total	100 00	100.00	100.00
Snlphur	....	....	....

The coal of those portions of the seam rejected on account of quality has also been analyzed, and the results are shown below. The rejected benches are known as follows, beginning with the uppermost:

1. Roof coal or rider seam, averages 3 feet.
2. Horn coal or cannel bench, 8 to 15 inches.
3. Splint coal, bottom of cannel, no longer rejected.
4. Soft bone coal, 10 to 12 inches, selected block.
5. Hard bone coal, 12 to 15 inches, average.
6. Hard bone, selected block.

Samples of all these benches were taken from mine No. 13.

Rejected Portions of Sunday Creek Coal (Lord).

	1.	2.	3.	4.	5.	6.
Moisture	5.75	4.48	2.78	5.88	5.38	6.93
Volatile combustible matter	31.03	37.80	45.46	34.31	31.46	35.14
Fixed carbon	40.48	47.77	39.92	49.15	42.25	47.63
Ash	22.74	9.95	11.84	10.66	20.91	10.30
Total	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	0.44	0.52	0.53	0.60	0.48	0.42

The portions represented by Nos. 2 and 3 ought both to go forward to market. No. 4 is rejected because of the extra amount of slack that it produces.

There is a thin layer of coal at the top of the rider seam that is known to be good, but it is not practicable to separate it from the rest of the bench. Analysis No. 1 stands for the average of the 3 feet of the seam. Under present conditions, it is excluded from market by reason of the ash that it carries, but this is its sole drawback. It is low enough in sulphur to answer for a furnace fuel. The time will surely come when coal of this character will be gladly taken in Ohio, of course, as second class fuel. It costs more trouble to burn it, but it contains a large and available stock of heat that the Commonwealth can ill afford to lose.

No better place will be found in which to trace the process by which the Middle Kittanning coal of the northern counties, with its remarkable steadiness of volume and composition, holding a thickness of less than 4 feet through county after county, becomes, all at once, the great coal of the Hocking Valley, ranging from 8 to 14 feet in thickness.

In Figure LXXIX, page 888, the structure of the seam is shown at Sheerhan's bank, near Moxahala, a short distance before it passes under the dividing ridge that marks the northern limit of Sunday Creek water. It is as follows:

Bone coal—Upper bench, rejected	22	inches.
False roof—Second slate	2–4	"
Top coal—Middle bench	8–10	"
Parting—First slate	1	"
Bottom coal—Lower bench	26	"

The type section of the Sunday Creek coal, as shown at Corning and Rendville, is represented in Figure XC*a*, and consists of the following elements, viz.:

Rider seam	30	inches.
Third slate	4	"
Upper bench. { Top coal, 42 inches; Bone coal, 24 inches }	66	"
Second slate	2	"
Middle bench	6	"
First slate	½	"
Lower bench	30	"

Comparing these two sections of the seam on the opposite sides of the dividing ridge, we find the following facts:

Moxahala Section.			*Sunday Creek Section.*		
			8.	Rider seam	30 in.
			7.	Third slate	4 "
			6.	Top coal	42 "
	Black slate.			Thin parting.	
5.	Bone coal	22 in.	5.	Bone coal	24 "
4.	False roof (second slate)	4 "	4.	Second slate (2–4)	2 "
3.	Top coal (middle bench)	8 "	3.	Middle bench (4–6)	6 "
2.	First slate	1 "	2.	First slate	½ "
1.	Lower bench	26 "	1.	Lower bench	30 "

The lower five elements of the two sections are seen to be substantially identical. In other words, the normal Middle Kittanning seam is present as an integral and unmistakable part of the "Great Vein." It constitutes the lowermost five feet of the Corning seam. It is somewhat changed in character from the northern phase, but chiefly in respect to the percentage of sulphur. There is a small reduction in the volatile matter and a corresponding increase in fixed carbon, but the change is but slight at the point where the present comparison is made. The formation of the thick coal of Corning is thus seen to be due to the superposition of two distinct benches of coal, aggregating 6 feet in thickness upon the normal seam. In other words, its composition is as follows:

Hocking Valley supplement	6 feet.
Normal Middle Kittanning coal	5 feet.

The statements now given cover the main points of interest so far as the normal or undisturbed coal is concerned. A few additional facts will be given as to the several mines.

Mine No. 3 has been worked more steadily and largely than any other of the field. Its coal is preferred in market by reason of the fact that it is more thoroughly cleaned than that of the adjacent mines, the screen bars over which it passes being 1½ inches apart. The nut coal is also more salable. All the coal comes out wet, and to accomplish its effectual cleaning, certain unusual stops are attached to the screens. This is the only mine in the valley in which colored miners are exclusively employed.

Mine No. 5, known as Rend's mine, has by lease 50 acres of unbroken coal, so far as workings have yet advanced. It is the only mine

of this valley in which mining machinery has been employed. The Harrison machine was introduced here at the opening of the mine, but it was not retained very long. The working faces were wet in so many instances that the machines were at a disadvantage.

Mine No. 7, known as the Baird mine, has by lease, 80 acres of the coal already described. No fault nor interruption has been found in its workings thus far, but it shows as regular a body of coal as is known in the valley.

The three mines named above are the only ones of the Corning and Rendville district that have not suffered more or less from unexpected and disastrous "wants" in the coal. Mines, Nos. 9, 11, 13 and 15 all came to trouble before their entries had been advanced 100 yards from the shaft. All of these but No. 13 are on the east side of Sunday Creek, and the explorations have been thorough enough to prove that there is very little to be looked for on that side. No. 15 is already abandoned and filled with water. There is very little more than the lower bench that can be depended on here, and it cannot be mined under present conditions of market, although the coal is of exceptionally good quality. About 34,000 cubic yards had been excavated when the mine was shut down, which stands for about the same number of tons of coal. Mine No. 11, located in Corning, was in the same condition, and would have been closed before this, had it not been for the recent purchase of the Rogers farm, which allows it to extend its working under the creek to the westward. By this means its life will be continued for 5 or 6 years.

Mine No. 9 has coal to the northward and westward for 2 or 3 years yet. On the east it has nothing. It met with failure of the coal before its workings were extended 100 feet from the shaft. It has produced thus far about 54,000 tons of coal.

Mine No. 13 is located exactly on the boundary between the regular and the broken coal. All of its southward running entries were at once involved in the fault. Many attempts were made to find coal beyond, but it is now demonstrated that there is an extensive "want" in that direction. To the west and north its coal is normal, and thus it has a large acreage still tributary to it.

Whenever the coal fails, it is from one of two causes. Either clay veins rise from the floor and interrupt its continuity, or the sandstone of the roof descends and takes the place of the seam, in part or entirely.

The first of these causes is much the more to be dreaded, as the experience of the field thus far has shown that when the coal fails from this cause, its failure is likely to be final, whereas, a narrow trough in the seam may be filled with sandstone, which, if crossed directly, may show the coal of proper thickness immediately beyond. As the coal approaches a clay vein, its character is changed. It becomes hard and curly, and thus more difficult to mine. The roof also becomes irregular and dangerous, and the advance of a few yards will often carry the miner from good ground into an entirely worthless mixture of coal, clay and shale.

Clay veins are the principal sources of trouble in all of the mines here named, but they are often more or less closely associated with the descent of sandstone, and it is the latter element that has worked the greatest harm in the region to the southwest of Corning. A great "want" in the coal has been known for a number of years in Sections 20, 21, 28, 29, 32 and 33, Monroe township. It has been connected by some with a similar want in the eastern sections of Salt Creek, but according to present knowledge they are distinct, a body of coal of full thickness occupying the interval. It now appears that this first-named failure of the coal extends directly through to Corning, and that the trouble of Mines Nos. 13 and 15 indicates the northern boundary of this "want," so that parts of Sections 22 and 15 must be added to the sections already named, making the total area of the "want" more than 2,500, and probably more than 3,000 acres.

Another serious interruption of the Great Vein, which has also been known for a number of years, is found in Sections 24, 25, and 36, of Salt Lick, and in the adjacent Sections 31 of Monroe, 36 of Trimble, and 6 of Ward township. No doubt other territory will also be found damaged by this want, but not enough is known to warrant the laying down of boundaries for either of these two or more broken ones. The hypothesis of an ancient water-course, coming from the north-west and eroding this territory shortly after the coal was formed, does not match well with present knowledge. It would require more than one river to explain the facts, and the erosion of the sea would seem to be a more probable agent of the waste than the drainage of the land.

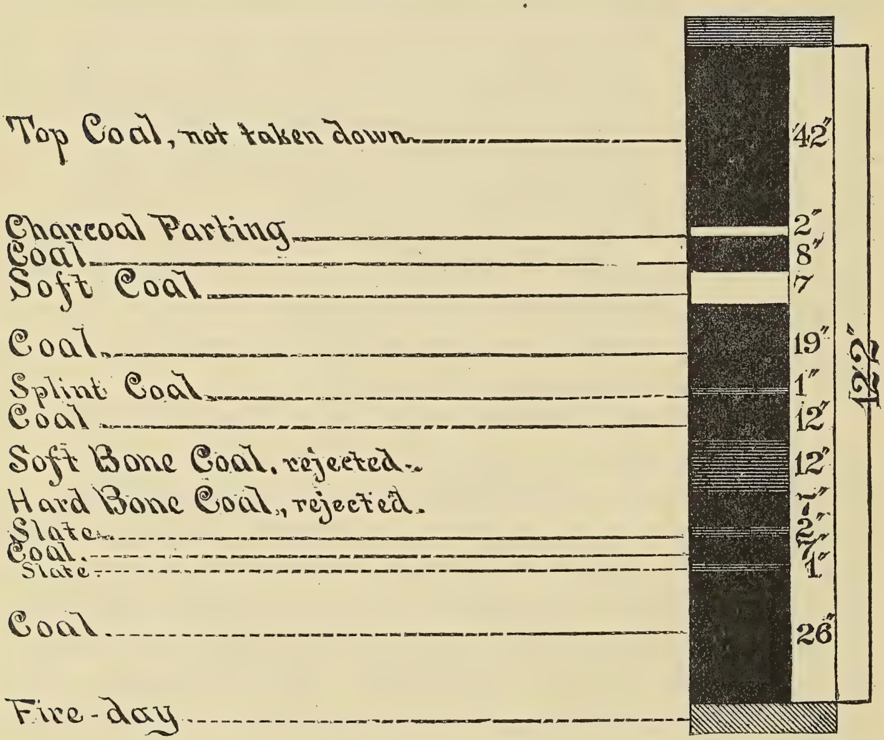
The facts as to these wants are indicated on the map of the Hocking Valley field which accompanies this chapter, but the qualification already made needs to be repeated, viz., that good coal may hereafter

be found in sections which are marked as deficient, the proving of the territory having been, in many cases, quite unsystematic and imperfect.

Mine No. 19, located at Buckingham, in Section 19, makes the last of the Great Vein mines of the township. It is one of the best equipped and best ordered mines of the State. It is justly counted by the Ohio Central Coal Company as one of its most reliable and valuable bodies of coal. The section of the coal is shown in the accompanying diagram:

FIGURE XCIII

STRUCTURE OF COAL AT MINE No 19, OHIO CENTRAL COAL CO. BUCKINGHAM.



The seam is here made to yield 5½ to 6 feet of coal, or about 6,000 tons to the acre. It shows few reductions or interruptions, so far as

worked, except that the bone coal already described is rejected. The composition of the coal is shown in the following analysis:

Composition of Buckingham Coal Mine No 19 (*Lord*). *Sampled from the Seam.*

Moisture	6.50
Volatile combustible matter	38.85
Fixed carbon	48.87
Ash	5.78
Total	100.00
Sulphur	0.82

The coal is a trifle lower in fixed carbon than most of the Great Vein, approaching the northern type of the seam in this respect, but in its low percentage of sulphur it shows one of the most valuable characteristics of the field to which it belongs.

Mine No. 21 of the Ohio Central Company is located in Section 23, Salt Lick township. It is but recently opened, but is already producing over 200 tons daily. The coal here shows its maximum thickness, so far as now known, for the entire field, viz., 14 feet. Of this, the roof coal makes 4 feet. It is believed that a larger yield will be secured from this mine than from any other yet opened in the Sunday Creek Valley. Thus far, there has been sent out 7½ feet of coal.

The entries driven southward have already found some trouble, it is to be said with regret, but how serious the interruption will prove, it requires further development to determine. The coal of this mine is continuous with that of the Shawnee mines, not more than one mile separating the workings of the two fields, and it must soon acquire the full character of the Shawnee coal. A large area is tributary to the mine, and it is expected that an output of 300 or 400 tons per day will be maintained for a long term of years. Its equipment is especially complete. The coal is level-free, the bottom lying a few feet above the valley of Hadley's Run.

The "Great Vein" was formerly supposed to be present throughout the whole township, but there now seems no reason to believe that it ever existed in the 6 north-eastern sections of the township, and in 19 sections, in which it was once laid down, it is known to be either faulty or wanting. The best of it is doubtless to be found in Sections 7, 8, 9, 10, 15, 16, 17, 18 and 19.

These statements complete the account of the Great Vein, in Monroe township, as far as present developments warrant.

The Upper Freeport Coal (No. 7) of Monroe Township.

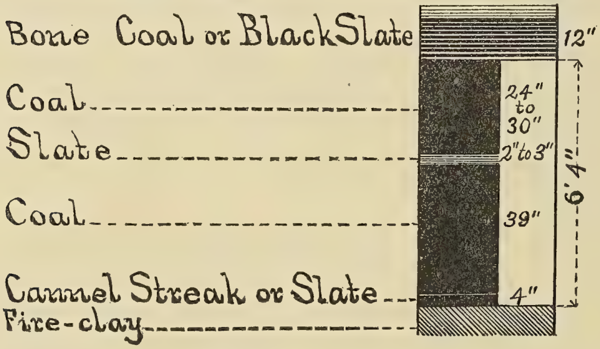
This seam has been opened at several points by the Ohio Central Coal Company within the township, but the only mines now in operation are the twin mines known as No. 12, and located near Middletown. They have been worked for 2 years. The coal in this neighborhood has long been mined for local supply, the seam having here acquired the name of the Norris coal by which it is quite widely known. Reference has already been made to the seam on pages 105–6. The Norris coal is there shown to be identical with the Bayley's Run seam. The Great Vein is wanting in this immediate neighborhood, and this fact has increased the difficulty of identification.

The Norris coal has the usual character of the Upper Freeport seam for this district. It is a 6-foot seam, divided into two benches by a main parting, in addition to which there are frequent thin bands of shale that serve to break and weaken the coal. A thin streak of cannel often directly underlies the coal.

The structure of the seam at the Twin mines is represented in Fig. XCII:

FIGURE XCII

STRUCTURE OF UPPER FREEPORT COAL AT MINE No. 12, OHIO CENTRAL COAL CO.



Its composition is shown in the following analysis:

Composition of Norris Coal, Twin Mines, No. 12 (Lord)—Sampled from the Seam.

Moisture	7.50
Volatile combustible matter	38.38
Fixed carbon	49.57
Ash	4.55
Total	100.00
Sulphur	1.10

The greatest thickness found in the mines is 6 feet 9 inches. The seam is quite steady. The cover is light and the roof is troublesome and dangerous. The coal finds use mainly in the production of steam.

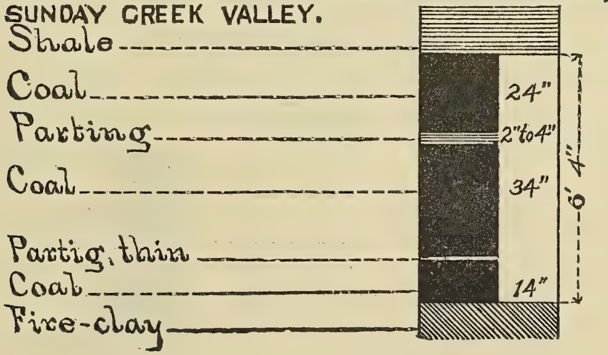
Mine No. 2 was worked in the same seam for a few months, but the coal proved uncertain and expensive to mine, and the workings were consequently abandoned. The thickness of the seam was $3\frac{1}{2}$ feet in its most regular portions. The mine was located in Section 5, Pleasant township. Other mines have been opened in the seam for local supply, but there is no inducement to extend their workings further at the present time. There is a considerable acreage that can hold the seam, but owing to its uncertainty, no calculations can be based upon it without careful proving of each particular area.

Coal Mines of Trimble Township—Sunday Creek Portion.

There is not much more known in regard to the condition of the great coal in this township than at the date of the last reports. One

FIGURE XCIV

STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT SHAFT MINE ONE MILE SOUTH OF JACKSONVILLE, SUNDAY CREEK VALLEY.



mine has been opened by the Ohio Central Coal Company, and is now operated by W. P. Rend. It is located in Section 7. The shaft is 130 feet deep, and the coal has a thickness of 6 feet 4 inches, partings included. The structure of the seam is shown in the accompanying diagram:

It is not certain that these partings correspond to those of the seam further north.

There is without doubt much valuable coal land of the great seam in this township, but it cannot be denied that the development of the region northward has thrown a cloud over it. It is no longer allowable in wise and honest mining enterprises to presume upon the steadiness of the seam or to count all its coal available. Each of these points must be properly tested, and every mining property must be proved and established for itself.

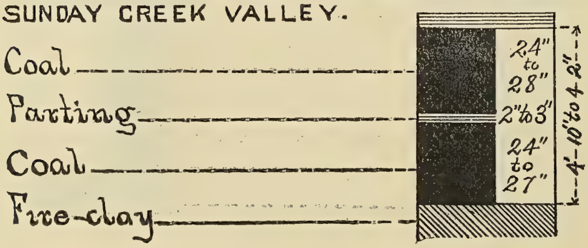
The Upper Freeport Coal in Trimble Township.

This seam has considerable value in the Sunday Creek Valley; Dover and Trimble townships, in particular, contain one of the most valuable basins of this coal in the western coal field. It has long been known in this district as the Bayley's Run coal, the same being taken from Dover township. It has been mined for the entire local supply of the Valley for many years, banks being opened on very many farms. The seam generally carries 4 feet and a few inches of coal in two benches, approximately equal, separated by a shale parting of two or three inches. So far as worked, the seam has proved itself steady and regular. There is no doubt that it will afford a safe basis for mining for the general market.

One railroad mine has lately been opened in the township at Jacksonville. A section of the coal is given below:

FIGURE XCV

STRUCTURE OF UPPER FREEPORT COAL (No. 7) AT JACKSON'S SHAFT. BELOW TRIMBLE, SUNDAY CREEK VALLEY.



The coal carries considerable sulphur, and lacks the strength of the great seam, but there is no reason why it should not take fair rank as a steam coal. By many who have used it as house fuel, it is highly valued, and by some it is preferred even to the great seam.

The Jacksonville mine is a well-equipped slope, prepared to send out 15 or 20 cars per day. At the present time, however, it is lying idle, all of the mining at this point being done in the shaft mine of the lower coal.

Among the numerous country banks in the Bayley's Run coal in the township, the Jackson bank of Mud Fork has as good a reputation as any. An analysis of its coal is given below:

Bayley's Run Coal, Johnson Bank (Lord).

Moisture	4.40
Volatile combustible matter	41.44
Fixed carbon	50.05
Ash	4.11
Total	100.00
Sulphur	3.37

The only fault to be found with the composition of this coal is its high percentage of sulphur. In the strength to endure handling, it is also deficient, but it compares favorably with the great seam in all other respects.

Coal Mines of Dover Township—Sunday Creek Drainage.

No coal of the Hocking Valley seam is worked in this portion of the township, but it has been found in several drill-holes with a thickness of 6 to 8 feet, at a depth of 75–125 feet. Its quality cannot, of course, be properly estimated until the seam is fully opened, but a favorable outcome is to be expected. This whole portion of the township is credited upon the map with the great seam, but the qualifications already made apply with full force to this territory. "Wants" will be found upon development, that, when duly represented, will destroy the uniformity of delineation, which is now employed, but the territory has a right, from the very meager and imperfect investigation thus far made, to a favorable prepossession. It is "Great Vein" territory.

The drill-holes now known to have reached the coal are as follows:

Section 22, coal	7 ft.
Fraction 11, coal	6½ ft.
Fraction 18, west half, coal	8⅙ ft.

The entire reliance of this portion of the valley for fuel supply has been and is in the Upper Freeport coal, here known as the Bayley's Run seam. It has been already described under the preceding section. It lies near the drainage level, and is universal throughout the valley. It reaches a maximum of 5 feet, and seldom falls to 4 feet. It is unquestionably an excellent basis for mining operations, and must soon come into use, now that transportation is at hand.

2. The Shawnee and Straitsville District.

Under this head will be included all of the Middle Kittanning coal (No. 6 of Newberry) of Salt Lick and Coal townships, that is 5 feet and more in thickness. A single small outlier in Gore township will also be included here. Such coal is found in Sections 11, 12, 13, 14, 15, 16, 17, 19, 20, 22, 23 and 24 of Salt Lick, in whole or in part, and also in Sections 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 and 36 of Coal township. The total area of "Great Vein" land in this district, including the "wants" known and undiscovered of the seam, is about 11,000 acres. The coal is known to be more or less defective in sections whose total area exceeds 3,000 acres, but it is to be distinctly understood that exploration has not advanced far enough to render possible any exact statement or any close estimate of the actual failures of the coal. Only those points are known, generally few and far between, where mine entries have come to trouble, or where drillers have reported defective coal, and the underground connection of these points is hypothetical and tentative.

The first methodical testing of the field is now going forward under the management of the large companies that are working here.

Through Sections 11, 12, 15 and 16 of Salt Lick township, the line of division between the normal Middle Kittanning seam of the northern counties, and the great seam of the Hocking Valley, passes, and the best opportunities afforded by the entire field are given here for observing the nature and mode of this surprising increase. The whole of the change is, in fact, accomplished within the workings of a single mine, as will be presently shown.

As in the Sunday Creek Valley, already described, the thick coal

here also consists of the normal seam, a little thicker and purer than the northern phase, immediately overlain by the Hocking Valley supplementary seam. The first, second and third benches of the great seam, the latter of which contains more or less inferior coal, as a rule, which is known as bone coal and soft coal, constitute the original seam. The supplementary seam was built upon it with but a very slight interruption. The original seam includes about 5 feet of the compound bed, leaving the same amount of coal, but of much less value, to be referred to the additional deposit.

This district produces more coal to the acre than any other in the State, the yield under favorable conditions being 9,000 tons of lump coal. The result is certainly no more than should be expected, when it is remembered that a seam 9 feet thick, carries 15,768 tons to the acre, the specific gravity of the coal being 1.29. Of this amount, 9,000 tons constitutes 57 per cent.

The Shawnee and Straitsville coal endures handling and transportation somewhat better than the coal of the Monday Creek and Hocking Valley districts, being inferior, in fact, to but one field of the State in this respect, viz., the block coal field of the Mahoning Valley. On these accounts it is especially adapted to the lake trade and for shipment to the north-west.

The mines of this district are without exception level-free or hill mines. Most of them are under good cover, and over much of the territory the hills rise high. The dip is quite regular, though there are, of course, local interruptions. It is fair to count on 25 feet to the mile, in a direction between east and south-east.

The roof, wherever normal, is very strong and safe, consisting of 10 to 20 feet of yellow or gray shales. Occasionally the shales have been cut away by descending sandstone. In this case, while the roof possesses greater strength then ever, it is still counted less desirable than shale, the coal being generally more or less troubled by the approach of the sandstone. The floor of the coal is a heavy bed of fire-clay, which, however, makes a fairly good bottom. It occasionally "creeps," in wet workings, or where entries and worked rooms are allowed to fill with water, but, with good management, no difficulty is experienced in this respect.

Shawnee.

The following mines are opened at Shawnee, viz.:

The New York and Straitsville Coal and Iron Company's Mines, known as the New York mines, the Vilas Furnace mines, "Hickory Withe" mines, etc., located in Sections 15 and 16.

The Furnace Coal Company's Mine, known as the Manly mine, located in Section 15.

The Shawnee Valley Coal and Iron Company's Mine, in Section 22.

The Fannie Furnace Mine, in Section 22.

The Newark Coal Company's Mine, in Section 21.

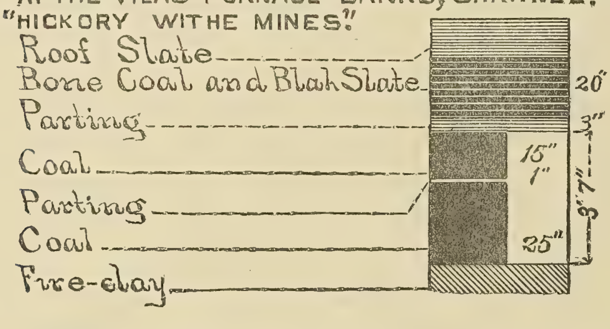
The XX Furnace Mine, in Section 21.

Card and Upson's Mine, in Sections 20 and 21.

The New York mines hold but little of the thick coal, almost their entire territory belonging to the normal or simple phase of the seam, but in their several workings the transition from the thin coal to the augmented seam is made, as is shown in the following sections:

FIGURE XCVI.

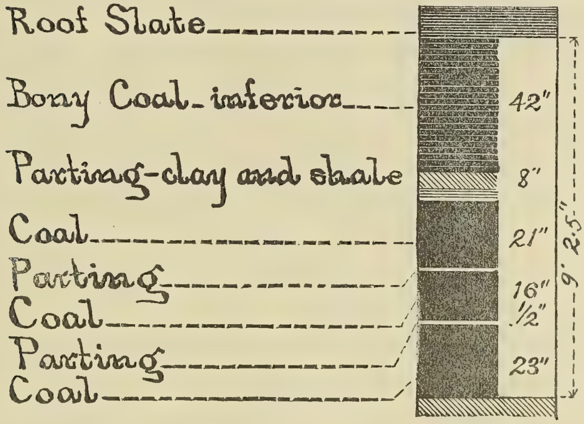
STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT THE VILAS FURNACE BANKS, SHAWNEE. "HICKORY WITHE MINES."



In Fig. XCVI, the structure of the coal in the northward running entries of the furnace mines is shown. It is obviously the same seam that we have followed through all the region north. As shown at McCuneville, it has already been figured in the preceding chapter. (See figure LXXXI, page 907). The McCuneville mine is on the farm adjoining the furnace property, and undoubtedly the coal holds the same general structure and measurements throughout the interval. The coal of this property strengthens on the extreme western boundary, the supplementary seam being there found, separated from the original seam by a thin bed of shale. It also takes the addition in the eastward running entries, where the section shown in Fig. XCVII was measured.

FIGURE XCVII

STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT "HICKORY WITHE MINES" SHAWNEE.



The additional coal is here bony and inferior, and it is separated from the normal seam by 8 inches of clay and shale. The line between the two phases of the seam is thus seen to pass through this property. The coal of these mines, coming almost entirely from the lower benches of the seam, has a good name in market, but it does not mine as large nor show as much strength as the coal of adjoining sections.

The Furnace Coal Company's territory, known commonly as the Manly mine, lies directly east of the New York mines, and shares in the general character of that property, except that a larger proportion of it contains the thicker coal. The line of division is found in the entries of this mine also. In the southern portion of its land, the seam acquires its full volume and value.

The Shawnee Valley and the Fannie Furnace mines are next reached. Both of them hold the Great Vein in good condition. The body of coal that begins here and that occupies Sections 21 and 22 of Salt Lick township, has been worked almost continuously through Sections 19, 20, 27, 28 and 29 of Coal township. Within these limits are eight large mines, and they unquestionably send out the best coal for lake shipment that at present is reached in the entire field. On the Shawnee side of the ridge, the mines are the two named above, together with the Newark, the XX Furnace, and the Upson mines. The double seam is here, in some respects, at its best. There is less waste in the coal than at any other point where it reaches 10 feet or more in thickness. Aside from the regular slates, there is not more than a foot to be

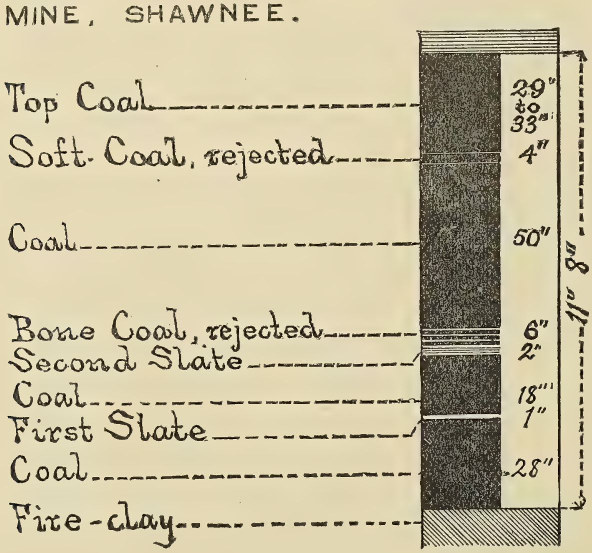
thrown out from the entire thickness. A few inches of inferior quality are always to be looked for directly above the second slate. Sometimes this band is called bone coal, and sometimes soft coal. Occasionally the whole bench is found fit for market. The average thickness of the rejected coal at this point in the seam, for the body now described, is 6 inches. Another layer of inferior quality, from 4 to 8 inches thick, occurs near the top of the seam. It is commonly a heavy and lustreless cannel, in which case it is known as "horn coal," but it is sometimes "soft coal," and again it is sometimes of the variety already described as "bone coal." There is always inferior quality at this level. A thin band next to the roof, and called by the miner white cap, is also rejected. It is about 2 inches thick.

The Shawnee Valley mine is one of the best ordered and equipped of the entire field. It was the first in the valley to introduce a wire cable for hauling out the coal. The cable now extends about $1\frac{1}{8}$ miles under ground. The trouble arising from a change of direction in the main entry has been ingeniously overcome, and the system has proved a decided success in every way.

The coal is represented in the accompanying figure, the section being taken from a room where the seam shows its full volume:

FIGURE XCIX

STRUCTURE OF COAL AT SHAWNEE VALLEY MINE, SHAWNEE.



The figure clearly represents the structure and general character of the seam. The roof coal, 29 to 33 inches in thickness, is not taken down in entries, nor in rooms, until pillars are drawn, as it makes an excellent roof under which to work. A portion of it is finally recovered. Its composition, as sampled in the mine, is shown below:

Roof Coal, 29 to 33 Inches, Shawnee Valley Mine (*Lord*).

Moisture	5.57
Volatile combustible matter	39.55
Fixed carbon	48.09
Ash	6.79
Total	100.00
Sulphur	——

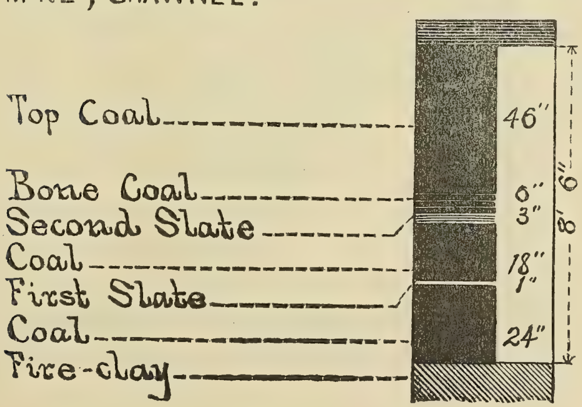
This analysis indicates that the top coal brings down to some extent the standing of the lower benches. The latter run higher in fixed carbon by 3 to 5 per cent., and lower in ash by about 2 per cent., but there is no warrant for leaving in any mine of the State any coal of this character that good mining can bring out.

The upper bench of the normal seam and the lower of the supplementary seam are run together in the 50 inches of coal that are shown above the second slate. The division comes about 5 feet from the bottom of the coal. The 4 inches of soft coal come in the place of the horn coal of other mines of the vicinity.

In the Fannie Furnace mine, which belongs strictly to the same body of coal, the entries being worked through from one mine to the other, the roof coal is not always found. A section of the coal taken here is shown in the following diagram:

FIGURE XCVIII.

STRUCTURE OF COAL AT FANNY FURNACE MINE, SHAWNEE.



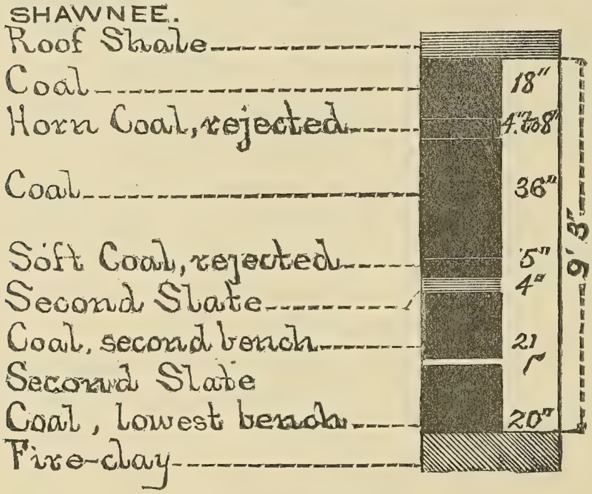
The seam where thus constituted yields a little less than 8 feet of coal. The output of this mine has established itself as a good furnace coal, but only the lower benches of the seam were used for this purpose.

The same conditions and descriptions apply in all respects to the mines of the Newark Coal Company and the XX Furnace.

Card and Upson's mine is the last of the Shawnee list. Its territory extends almost to the northern limit of the field. It comprises an undisturbed and regular body of the great coal, which averages 9 feet in thickness, and in which no interruption worthy the name has yet been found. The structure of the seam is shown below:

FIGURE C

STRUCTURE OF COAL AT UPSONS MINE, SHAWNEE.



The seam was carefully sampled in an average room of this mine, and analysis shows the composition given below:

Coal of Card and Upson's Mine, Shawnee (Lord).

Moisture	6.09
Volatile combustible matter	35.61
Fixed carbon	51.44
Ash	6.86
Total	100.00
Sulphur	0.84

The ash is probably a trifle higher than some other portions of the seam might have shown. Its relatively large amount results from the

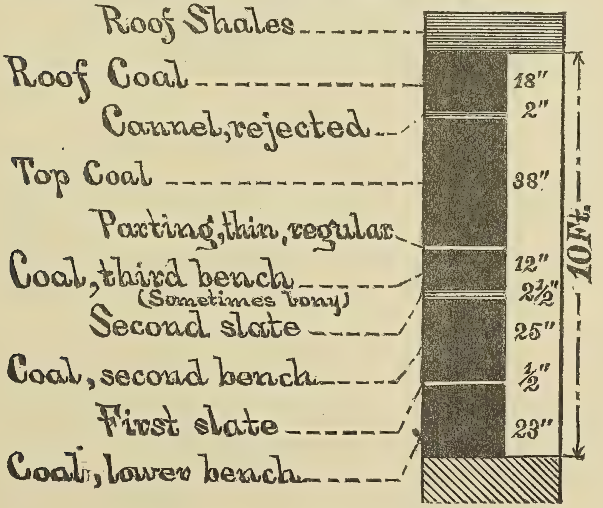
great thickness of the top coal, but this mine has gained as good a name as any in the thick coal.

There was shipped from Shawnee, in 1883, 420,000 tons of coal, of all descriptions. The four furnaces of the town, when in blast, require about 60,000 tons per year additional to the amount sent out to the general market.

In the interval between Shawnee and Straitsville the valley of Rock Run is cut down a little below the level of the coal, and a new mine was opened here in 1883. The mine commands somewhat more than 200 acres of coal land, situated in the south-west quarter of Section 21, Salt Lick township, and in the adjoining Section 28 of Coal township, the mine being opened on the latter. It is commonly known as the Rock Run mine, though its full designation is Mine No. 3, of the Columbus and Hocking Coal and Iron Company. It is reached by a branch road, built by the Baltimore and Ohio Company, from the Newark branch below Shawnee. The coal is worked by the company above named, under lease from H. Hazleton, on a royalty.

This new mine shows as fine a body of the Great Vein as there is in the Hocking Valley. The coal is steady in thickness, and apparently also in quality. Its structure is indicated below:

FIGURE 6a.
STRUCTURE OF COAL, ROCK RUN.
C. & H. C. & I. Co's MINE No 3.



The composition of the coal, as sampled from the entire seam, is as follows:

Coal of Rock Run Mine (Lord).

Moisture	6.15
Volatile combustible matter	38.53
Fixed carbon	48.95
Ash	6.37
Total	100.00
Sulphur	——

This analysis is a little disappointing in the low percentage of fixed carbon, but it is to be remembered that it is the average of 9 feet of coal, of which 5 belong to the upper benches.

The parting between the soft coal over the second slate and the top coal is thin but regular. It is the separating line between the normal and supplemental seams. The soft coal runs as high as 12 inches at times, but it is often reduced to 4 or 5 inches. Two inches of horn coal or cannel are split out of the upper coal, the streak lying 18 inches below the roof. The coal above the cannel is not taken down in entries nor in rooms, until pillars are drawn, when all comes out.

Analysis was made of single samples from the lower bench, and also from the coal above the cannel, the results of which are given below:

Composition of Coal from Rock Run Mine (Lord).

1. Coal above the cannel.
2. Coal from bottom bench.

	1.	2.
Moisture	6.33	6.35
Volatile combustible matter	38.51	38.49
Fixed carbon	46.84	50.81
Ash	8.32	4.35
Total	100.00	100.00
Sulphur		

These figures, like those previously given, clearly indicate the effect of the top coal upon the output. The fixed carbon is reduced and the ash is increased by it. Wherever the seam is greatly thickened, a reduction of quality is inevitable.

Straitsville.

The following mines are now worked at Straitsville, viz.:

Troy mines, old and new, C. & H. C. & I. Co., No. 5.
Straitsville Central mine, C. & H. C. & I. Co., No. 7.
W. P. Rend's mine.
Straitsville Mining Company, C. & H. C. & I. Co., No. 33.
Straitsville Coal Company, or Plumer Hill, C. & H. C. & I. Co., No. 35.
Consolidated Coal Company's Mine, Old Straitsville. Lately given up.

The next mines to be reached in the particular body of coal that we have been following, are the two openings known as the Troy mines, or as No. 5 of the Columbus and Hocking Coal and Iron Company. These mines are as widely known as any in the field, and their output is as highly esteemed, especially for the lake trade. The seam shows its full thickness and its full strength. All of the favorable statements applied to the Shawnee Valley and Rock Run coal are also applicable here. The new mine is advancing to its northern limit, which is also the limit of the coal, not more than 800 feet intervening between the present workings and the outcrop. The old mine gets under heavy cover from the first.

To the Excelsior mine of the Wagoner Coal Company of Summit county there was given, on a preceding page of this volume, the credit of making the largest output, in a single day, of any mine in Ohio, but that statement must be withdrawn and a higher place in production must be assigned to the Troy mines. From the new mine, 1,573 tons have been loaded in a single day of 9 hours, and from the old mine, 1,499 tons in 9 hours, according to the testimony of James W. Heppel, the inside boss.

In several adjoining rooms of the new mine, reptilian tracks were found in the roof shales, the first thus far reported in Ohio. They will be described on a succeeding page if space can be secured.

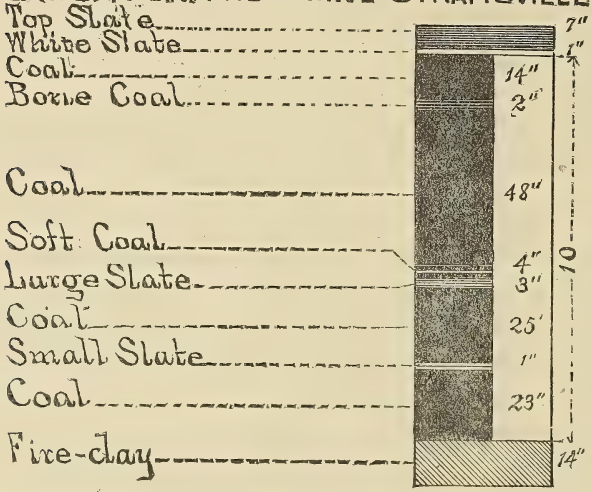
The structure of the coal is shown below:

The soft coal is given as 4 inches thick, but this measure is a minimum. There are occasionally found, however, rooms in which no part of the bench to which the soft coal belongs is rejected. The seam yields on this property fully 9 feet of clean coal.

The mine of the Consolidated Coal Company, known as the Old Straitsville mine, occupies the outermost spur of the Great Vein, to which the Troy mine belongs. Its coal is all included in Section 19'

FIGURE C1

STRUCTURE OF COAL IN MINE No 5 OF C&H C&I Co..TROY MINE STRAITSVILLE



of which it forms about one-third, and it agrees in all respects with the coal already described. There are probably 50 acres of coal left in this property, which has just passed into the hands of the Columbus and Hocking Coal and Iron Company. Its coal, except, of course, near the outcrop, has as good a reputation as any coal in the field.

Passing to the southward, from the Troy mine, the first mining property to be reached is, that known as the Straitsville Central Mining Company, now known as mine No. 7, of the Columbus and Hocking Coal and Iron Company. The property originally included about 600 acres of coal land. The character of the coal agrees with that of the Troy mine in all respects. This is the only Straitsville mine in which machines are used upon the coal. The Lechner machine was introduced here early, and its work has been very satisfactory. The new machine, especially, is very effective and rapid. Four machines are now employed in the mine, and a large percentage of the coal is produced by them.

The coal of the Straitsville Central mine has the composition shown below. The whole seam was sampled in an average room :

Coal of Straitsville Central Mine. (*Lord*).

Moisture	6.66
Volatile combustible matter	36.07
Fixed carbon	50.92
Ash	6.35
Total	100.00
Sulphur	1.01

The section and structure of the seam agree with those last given. This mine has a long lease of life, inasmuch as by it a large and valuable body of coal can be best reached.

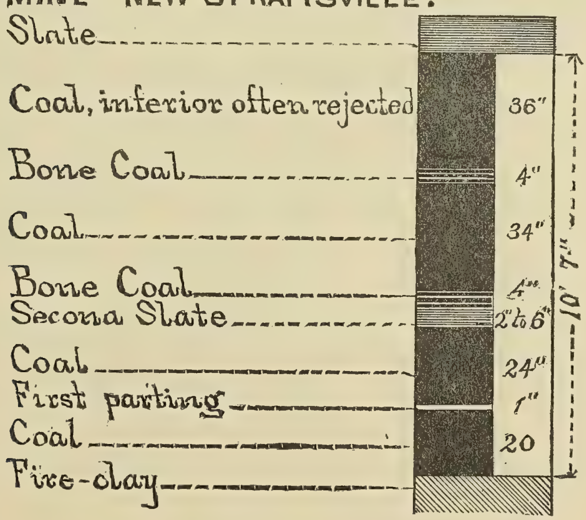
Contiguous to the last-named mine, and also to the Troy mine, and forming part of the same body of coal, is the mine operated by W. P. Rend, under lease from the Columbus and Hocking Coal and Iron Company. It is known as Mine No. 6 of this corporation. No separate description is required.

Mines Nos. 33 and 35 of the syndicate (Columbus and Hocking Coal and Iron Company), formerly known respectively as the Straitsville Mining Company's and the Straitsville Coal Company's mines, originally included about 750 acres of coal lands in Sections 29, 30, 31 and 32 of Coal township. Mine No. 35 is also known as the Plummer Hill mine.

A section of the coal in one of the best rooms of No. 35 is shown herewith :

FIGURE CII

STRUCTURE OF COAL AT PLUMMER HILL MINE NEW STRAITSVILLE.



The ordinary measure falls a few inches below these figures, and on the north-eastern side of the mine the uppermost bench is wanting for a considerable area, reducing the seam to 7 or 7½ feet.

The parting between the normal and supplemental seams is everywhere found. The upper bench of the normal seam is generally thicker than it is shown in the figure, there being nearly a foot to be rejected here, including the second slate.

The coal of both of these properties was found to be seriously interrupted in the front hill, by sandstone "horsebacks" proceeding from the roof, and by the associated clay veins that rise from the floor, and large outlays have been incurred in driving through the low coal and the rock. The direction of the sandstone channels is approximately south-west, but the clay veins, though associated with and apparently due to the descending rock, are irregular in their boundaries, and are, therefore, much more confusing than the sandstone faults.

These mines, among others, illustrate the modes in which ultimate loss is incurred by unskillful management in mining. The coal of this field is easy of attack, and, at the outset, mines seem to have been located and worked with reference to immediate results, without definite and well-considered plans as to their continuous operation. As a consequence, it has been found necessary already to shift, at large expense, tipples and tracks, while the underground workings present a dreary display of weakened and endangered entries, for which adequate protection can not now be easily secured, and a wilderness of lost pillars and props. Blocks of coal are also cut off, occasionally, from their natural routes of egress, and can be gained only by increased expense. The amount of coal needlessly sacrificed in the Straitsville mines, by want of proper knowledge and skill in opening and managing them, will reach a high figure. If this field had been, from the first, handled with the same care and skill that characterize its recent management, it would have made its present value greater by more than 200 acres of solid coal. In other words, more than 200 acres of coal have been needlessly lost to the field.

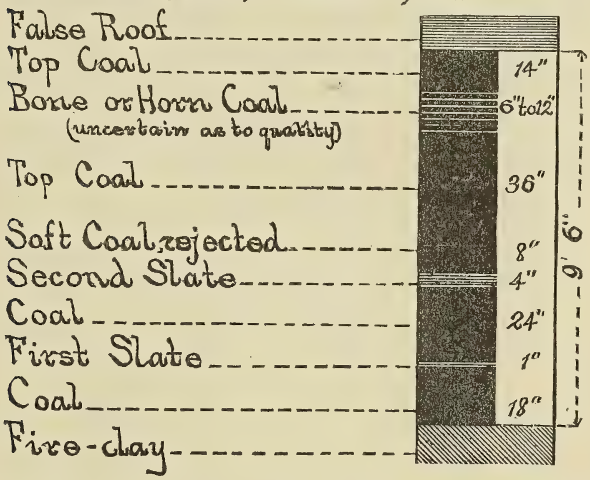
The front hills of these two properties have been almost entirely worked out, and the solid coal lies a half mile or more from the tipples. More than 200 miners are now engaged in drawing stubs and pillars in these mines. In many cases the coal has become "croppy" by long exposure, and can no longer go into market as first-class fuel.

The coal has great value on the western side of these properties. On Lost Run it shows a thickness of 12 feet.

The only remaining mine to be considered in this division is that formerly known as J. S. Doe & Co.'s mine but now known as Mine No. 9, of the syndicate. It is opened on the Lancaster and Straitsville Mining Company's lands. The coal is here at its western outcrop, lying in the hill-tops with small area and light and treacherous cover. The structure is shown in the appended figure :

FIGURE CIII

STRUCTURE OF COAL AT C&H COAL AND IRON CO'S MINE NEAR STRAITSVILLE. (J.S. DOE'S & CO'S, FORMERLY.) No 9



Two analyses of this coal were made for the survey, the seam being in one case sampled from a room, and in the other from the bank cars. The results are shown below :

Coal of Mine No. 9, (*J. S. Doe & Co.*) (*Lord*).

1.—Sampled from seam.
2.—Sampled from bank cars.

	1.	2.
Moisture	7.09	6.60
Volatile combustible matter	36.61	34.72
Fixed carbon	52.00	52.56
Ash	4.30	6.17
Total	100.00	100.00
Sulphur	1.19	0.64

These figures show a coal of great excellence; its reputation in market bears out the analysis.

3. The Monday Creek District.

This district embraces all the coal lands and coal mines of the great seam in Monday Creek township, the furnace mine in Gore township, all the coal in Green, all in Ward township, except Section 19, the west line of sections of Trimble, and as much of York and Dover townships as is included in the Monday Creek and Snow Fork Valleys. Ward township is the heart of the district, and thus it may be counted the heart of the Hocking Valley. In the northern portion of the district the coal holds very nearly the thickness but not the strength and hardness of the Straitsville coal, but in much the greater part of the area named the coal falls decidedly below the Shawnee and Straitsville coal in measurement. The decrease is wholly in the top coal or the supplementary seam, and to this fact is due the improvement in chemical quality which is to be noted here, and to it also is due the loss of strength or hardness in the coal. It has already been made apparent that the upper coal always decreases the fixed carbon and increases the ash of the seam when it is counted in, and it is also true that it always yields the firmest and strongest coal.

The coal of the Monday Creek district ranges, as a rule, between 6½ and 8½ feet in thickness, of which about 4 feet belong to the two lower benches. The third bench, which is the highest of the normal seam, yields merchantable coal in a number of mines, although the same tendency to poor quality that is found in other portions of the field frequently shows itself here. It would, no doubt, be better for the standing of the coal if this piece of coal were always rejected. The supplementary seam almost always carries some waste matter, generally, in the shape of a layer of horn coal or cannel. In one or two mines this cannel becomes merchantable. The roof coal is uncertain in quality, and a part of it is often left in the mine. From some rooms of a mine it can be safely taken, while from others all must be rejected.

Considered with reference to both quality and quantity, the Monday Creek district constitutes the best part of the Hocking Valley Coal Field. It yields a better coal than Straitsville or Shawnee produces, so far as chemical constitution goes, for the reason already given that there is in it less of the top coal. It does not bear handling as well as

those coals, however, and there is less of it to the acre. While it is not superior in quality to the Nelsonville coal, it still outranks it in value, because there is more of it.

Fifteen well-equipped mines are now established in the district. Four or five of them that are at work upon outliers of the coal in Monday Creek and Green townships are near their limits, but most of the mines are at the edge of what seems one of the largest bodies of unbroken coal in the entire field.

The Baird Furnace Mines.

The Furnace mine is located in the largest of the outliers of the great seam in Monday Creek township, in Sections 11 and 14. There are nine of these outliers that occupy as many of the separate hill-tops and ridges of the township, but their combined acreage is small. The Furnace tract originally comprised about 50 acres of coal, but of this amount at least a fifth has already been mined. Winona Furnace owns the coal of the second largest outlier of the township, located in Sections 14 and 15. There was originally about 20 acres of the coal, and of it more than half has been already mined.

A small tract of 4 or 5 acres on the Bowman (formerly the Folsom farm), in Section 10, has been worked in a small way.

The coal of these several outliers is represented in the following sections:

FIGURE CIV
SECTION FROM BAIRD'S COALMINE

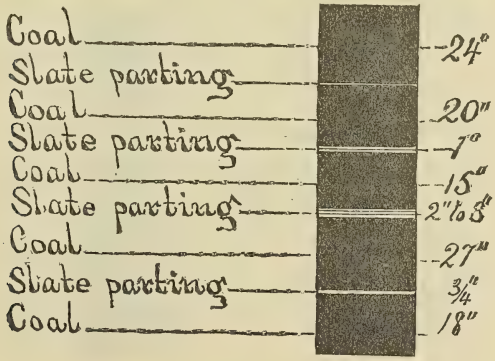
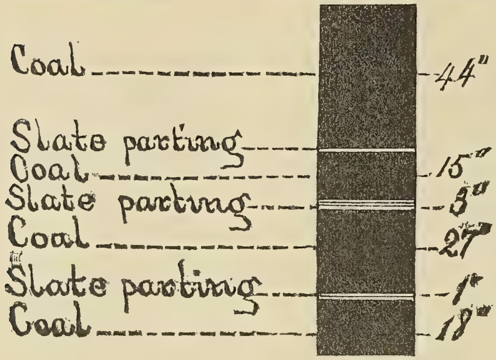
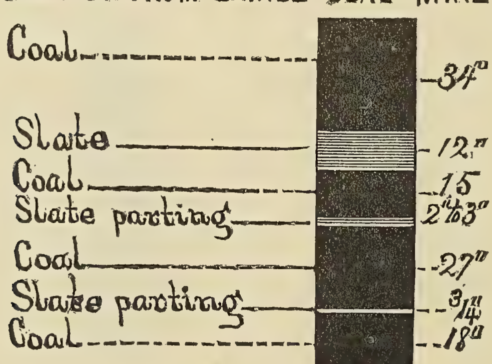


FIGURE CVI
SECTION FROM THE BOWMAN BANK



The next exposures of the seam to the north of those here named contain the normal seam only. The change from thin coal to thick can be well traced in this township, and it agrees entirely with the mode of change reported from the other portions of the field. It consists in the superposing of a new coal seam upon the normal seam, but the latter is often slightly augmented in volume and somewhat improved in character when it is thus covered. The Baird mine must be very near the line of division if, indeed, this line is not to be found within the limits of the furnace property. The warrant for expecting the change very soon is found in the following section, Fig. CV, which was taken in one of the entries of the Furnace mine at its northernmost extension:

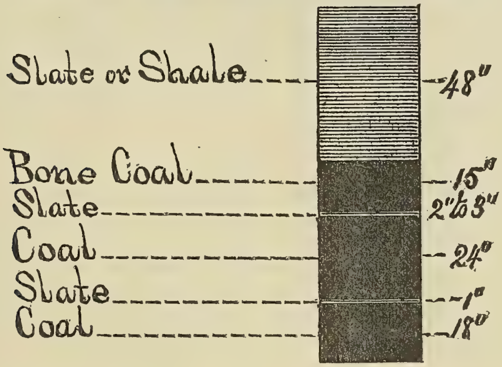
FIGURE CV
SECTION FROM BAIRD'S COAL MINE



By comparing this section with Fig. XCVII, it will be seen that the same state of things is found here that has been already described in the New York mines of Shawnee. A layer of shale, 12 inches thick, is found between the normal and the supplemental seams. In Fig. CIV the same parting is seen, but only one inch in thickness. Going northward, the upper coal is rapidly reduced, and will very soon entirely disappear. The seam is mined by G. Martzloff, on Section 2, Monday Creek township, about 1 mile north of the Furnace mine. At this point it has the structure shown below:

FIGURE CVI b

SECTION FROM J. MARTZLOFFS FARM



But little beside the normal seam is worked in the furnace mine. The roof coal, to the extent of one or two feet, is not taken down, and at the outside not more than 18 or 20 inches of the supplemental seam is found available for furnace use.

This body of coal has a historic interest from the fact that it was the first of the Hocking Valley to be applied to iron manufacture. The successful manufacture of iron from the native "limestone (or Baird) ore" with this coal as the sole fuel, which was begun here in 1874, by Mr. Samuel Baird, now deceased, is one of the important points in the development of this field. The great seam was proved to be one of the few bituminous coals of the country that can be successfully used in its natural state in iron manufacture, and since that time the development of this important interest has been very rapid. There are 13 furnace stacks now in the field that make the Hocking Valley coal their sole reliance for fuel.

The remaining outliers of the great coal of Monday Creek township agree exactly with those already described. All are small, ranging from 1 to 5 acres.

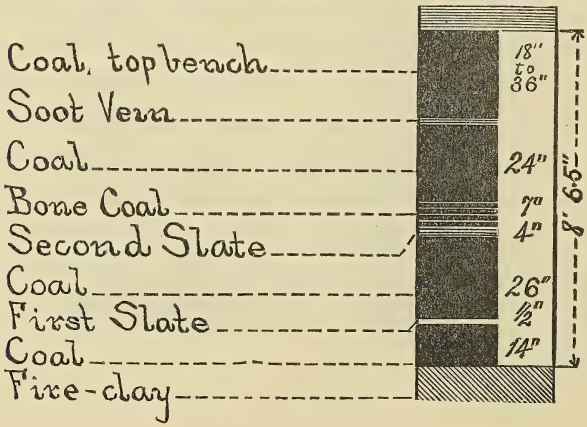
A single important outlier remains to be described in Gore township. It is located in Section 35, and the furnace mine of the Thomas Iron Works is established in it. The original area of the coal was about 120 acres. The first coal of the region successfully used in a blast furnace was the Baird coal, as has been already stated. This occupies an outlier, lying high and dry in the hill-top. It seems to have been held that these outliers were in some way best adapted to iron manufacture, as the mines of three furnaces are located in similar outliers along this western outcrop of the great seam. Analysis of the coal does not show any adequate ground for such selection.

In Green township there are found 7 outliers of the coal, together with the large body, also an outlier, that is situated between the Monday Creek and Hocking River Valleys.

Four of the smaller areas are tributary to the Craft's Furnace Mine, No. 13, C. & H. C. & I. Co. They are situated in Sections 11, 12 and 5, and are already worked far towards exhaustion. Lying high in the hills, the cover of the coal is poor, and a great amount of timber is required to keep up the roof. There is more than the usual danger in mining here.

The structure of the seam in these outliers is shown in the following figure:

FIGURE CVII.
STRUCTURE OF COAL AT CRAFT'S FURNACE MINE. No. 13

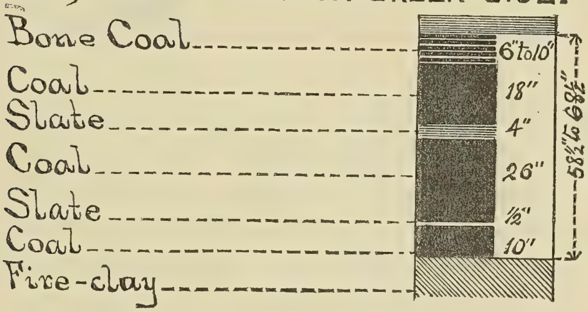


This figure needs no explanation, as it agrees closely with those taken from the fields to the eastward. The coal has proved itself a satisfactory furnace fuel in all respects.

The main body of coal of this seam, in Green township, is that which belongs to Peter Hayden. It occupies Sections 1 and 2 entirely, and parts of 3, 7 and 8. The coal is carried out on the Hocking river side, a mine locomotive running under the entire hill. This property has yielded a vast amount of coal, having a larger acreage worked out than any other in the field. The section of the seam on the Sunday Creek side is shown in the accompanying diagram :

FIGURE CX

STRUCTURE OF COAL AT HAYDEN'S MINE, EAST OR MONDAY CREEK SIDE.

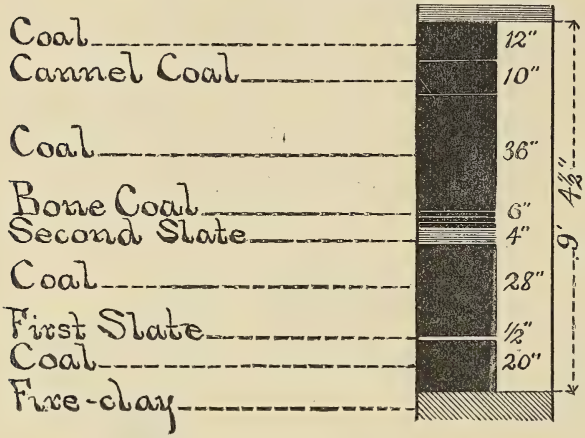


The seam has undergone a change, as will be seen in the interval now passed. The lower bench is reduced to 10 inches, and the whole seam has fallen to about 5 feet of coal.

The coal of Ward township has already been referred to as in some respects the most valuable body of coal included in any single township of the Hocking Valley. There are eight mines now in operation in it, and their output covers much of the choicest coal that goes out of the field. The first to be reached in descending the valley are the three mines of Sand Run and the Carbon Hill Mine. One of the Sand Run Mines and the Carbon Hill Mines, both formerly known as the Somers Mines, now belong to the Columbus and Hocking Coal and Iron Company, being known respectively as Nos. 15 and 17. The two remaining Sand Run Mines belong respectively to Sackett and Smart and the Consolidated Coal Company.

The Somers Mine, on Sand Run, shows the following structure of the coal. (Mine No. 15) :

FIGURE CIX
STRUCTURE OF COAL AT C.&H. COAL AND IRON CO.'S MINE No 15 SAND RUN (SOMERS' MINE)

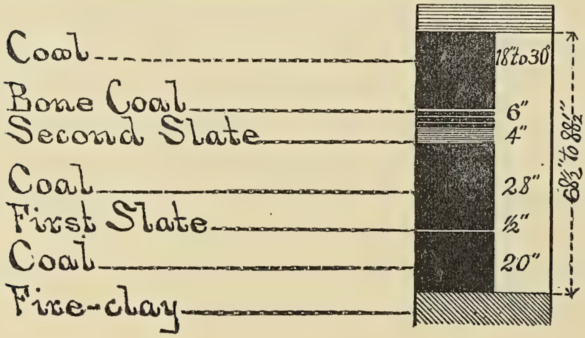


A peculiarity of this mine is, that the 10-inch cannel is a marketable coal. It yields about 10 per cent. of ash, but burns cheerfully, and makes in some respects a desirable grate fuel. If a careful selection is maintained, a good quality can be assured, but part of the bench is long-grained and high in ash, degenerating into slate. Permanent market is not yet assured for this part of the seam.

The Sand Run coal ranges from 7 to 9½ feet. On the Carbon Hill side, the seam does not often overrun 7½ feet.

The structure of the Carbon Hill seam is represented in the following figure. (Mine No. 17):

FIGURE CVIII
STRUCTURE OF COAL AT C&H. COAL AND IRON CO.'S MINE No 17 CARBON HILL (SOMERS MINE)



The great value of the coal in this portion of the field is, in part, due to the fact that the two lower benches are so fully developed here, their aggregate thickness equaling, or slightly exceeding, 4 feet. The composition of the Carbon Hill coal is shown in the following analysis:

Coal of Carbon Hill Mine. (*Lord*).

Moisture	5.26
Volatile combustible matter	36.12
Fixed carbon	54.59
Ash	4.03
Total	100.00
Sulphur	.64

There is but very little coal in Ohio that is better than this.

The Consolidated Coal Company's mine on Sand Run is mining 84 per cent. of its coal at present by machines. The Butler or Harrison machine is used here with great satisfaction. This mine commands the coal of 180 acres, and is of exactly the same quality as that last described. The coal is at long intervals cut by clay veins, and the roof rock sometimes comes down into the coal, but no very serious interruptions have yet been encountered. The use of the drill in proving territory in front of trouble in the seam, is coming into general use. The drill is a much less expensive tool with which to explore than the miner's pick.

Sackett and Smart's old mine proved very faulty, the coal being cut down and out through so much of it as to make the mining uncertain and unprofitable. This company has a new lease, just beyond the old Somers mine, and the drill shows 9 feet of coal, including the cannel, in that direction. The coal is entirely represented by that of the Somers mine.

Longstreth's Mine, now No. 19, of the syndicate, is in the same noble body of coal that is now being considered. Five Lechner mining machines are in operation here, and have been from the opening of the mine. The mine ranks amongst the largest, as well as the best, of the Hocking Valley. The structure and composition of the coal are represented in the preceding figure and analysis, the coal being continuous and identical with that of the mines before named. The composition is given on a succeeding page.

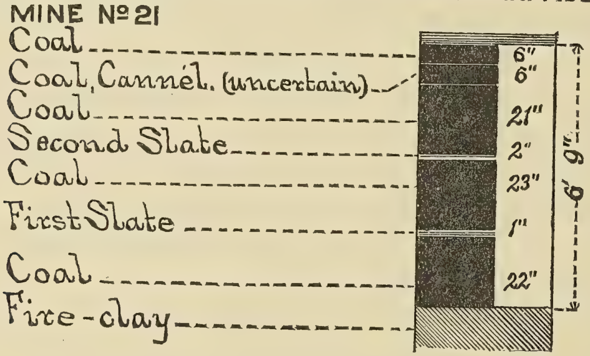
The Monday Creek Furnace mine belongs to the same portion of the field, as does also the well-known Cawthorn farm. The coal has been mined on a small scale on the last-named property, and maintains the same high character that marks the rest of the Monday Creek coal.

The next mines to be reached are those of the Akron Iron Company, now Nos. 21, 23, 25 and 27 of the Columbus and Hocking Coal and Iron Company. The first three are drift mines; No. 27 is a shaft mine. No. 25 embraces in reality two mines, the Upper Freeport seam being mined directly above the great seam, the coal being delivered by the same chute.

The structure of the seam in the Furnace Mine, No. 21, is shown in the following figure:

FIGURE CXI

STRUCTURE OF COAL AT AKRON FURNACE MINE No 21



This figure fairly represents the seam throughout this immediate district, though the top coal is sometimes found a little thicker than is here shown, but no great value is added by its increased volume. About 6 feet of clean coal are found here, and of this the two lower benches form nearly two-thirds. It is their relative predominance in the output that gives to this coal its high character. Its composition is shown in the appended table.

As was said of the last analysis reported, viz., that of the Carbon Hill mine, there is but very little better coal in Ohio than this. The close agreement of these analyses and that of the coal of J. S. Doe & Co.'s mine, given on page 957, is to be observed. The last-named mine belongs in reality to the same tract with the former.

1. *Coal of Akron Furnace Mine (Lord).*
2. *Caal of Longstreth's Mine (Lord).*

	1.	2.
Moisture	5.68	8.48
Volatile combustible matter	35.79	36.97
Fixed carbon	54.13	52.42
Ash	4.40	2.13
Totals	100.00	100.00
Sulphur	0.58	0.47

For convenient comparison, the analysis Doe's Coal will be here repeated :

1. *J. S. Doe & Co.'s Mine, average of two analyses, No. 9, C. & H. C. & I. Co.*
2. *J. H. Somers' Mine, No. 17, C. & H. C. & I. Co. Lord.*
3. *Akron Furnace Mine, No. 21, C. & H. C. & I. Co. Lord.*

	1.	2.	3.
Moisture	6.84	5.26	5.68
Volatile combustible matter	35.66	36.12	35.79
Fixed carbon	52.18	54.59	54.13
Ash	5.21	4.03	4.40
Total	100.00	100.00	100.00
Sulphur	0.91	0.64	0.58

These analyses, made from a differential and thorough sampling of the seam, in mines 10 miles apart, show the Monday Creek district to be the heart of the Hocking Valley coal field, as has been already claimed for it. The seam here reaches its highest value, if both quality and quantity are taken into account. In percentage of sulphur, the Monday Creek coal stands decidedly in advance of the other coals of the State. It does not quite equal some other Ohio coals in fixed carbon. In ash, J. S. Doe's coal runs higher than the rest, solely on account of the greater thickness of top coal in this mine.

The mines of Akron Furnace belong in the valley of Snow Fork, rather than in the Monday Creek Valley, but the former district is included, in this review, in the Monday Creek field.

The Snow Fork Valley, above Buchtel, contains two mines in the

Hocking Valley seam, viz., the Orbiston mine, connected with Helen Furnace, and the Murray City mine. The seam lies not far above the level of the water between Murray City and Buchtel. At the former place it is partly below drainage. The Lower Freeport sandstone is in strong force through the entire valley, and lies heavy upon the coal in a great many exposures, reducing its upper benches and also affecting the quality of the coal below, to some extent. Still the evil effects of the sandstone do not prove as serious as they were thought to be before mining was begun here.

Murray City Mine.

The Murray City mine was opened by Gosline and Barber in 1883, but was soon after sold to the Columbus and Hocking Coal and Iron Company, by whom it is now held and worked. It is well equipped and well regulated in all respects, second to none in the valley as to convenience and economy in handling the coal. It was here that the Mitchell automatic tipple was introduced. The coal is reached by a short slope, cut in the solid sandstone. The entries run very nearly on the ends of the coal. The hauling is done by an endless wire cable, which now extends 1,300 feet from the mouth. At the present time the mine is capable of producing 40 cars per day.

A little water gathers at the foot of the slope, but the dip of the workings is such as to make the drainage thus far a simple problem. Though wet at first, all parts of the mine are now furnishing dry and safe working places. The miners find it fully equal to any part of the field so far as ease in getting coal is concerned. They can easily maintain a daily output of 3 or 3½ tons to the man.

The coal mines large, but is a little inferior in strength to the coal of Straitsville and Shawnee, on account of its smaller proportion of top coal. It is, however, well esteemed for the lake trade.

Only one clay vein has yet been struck in the entire workings of the mine, and the coal has never been cut below 6 feet by the sandstone, so that, as far as proved, this body of coal takes rank with the best in steadiness and favorable conditions.

The coal falls considerable below the Straitsville measure. The section is as follows:

Lower Freeport sandstone, massive.

	Roof shales, uncertain	0–6 feet.	inches.
	Rider coal, coarse and sulphurous, rejected	12	"
	Cannel bench, generally coarse, rejected	12–15	"
	Upper slate	4	"
Coal.	Upper bench	30–40	"
	Second slate	2–4	"
	Middle bench	21	"
	First slate	1	"
	Lower bench	21	"

The thickness of the mineable part of the seam is thus seen to range between 6 and 7 feet. As usual, a band of about 6 inches directly above the second slate needs to be rejected. This portion is here not only soft, but is also whitened with sulphates. No account whatever is made of the upper portions of the seam. The cannel is in a few places curly and clear, but generally it is very coarse and slaty. The rider seam is also altogether worthless.

The Helen Furnace mine at Orbiston does not thus far come quite up to the best records of the valley. The sandstone has proved intrusive in many of the workings, cutting down the coal to 5 or 5½ feet. There is, however, a large acreage on this property where the coal is undoubtedly of standard proportions and quality.

4. The Nelsonville District.

Under this head a brief account will be given of the remaining mines of the Hocking Valley field. A few of these are in reality located in the Monday Creek Valley, but their coal comes from the same body that has been so long worked and so widely known as the Nelsonville coal. In some cases the entries of the Nelsonville mines have been driven through the hill to Monday Creek Valley, and the works established in the latter are merely removing the coal more conveniently than by the original entries. The number of separate mines in this district is larger than in the previously named divisions of the field. Not less than 20 mines are equipped as shipping banks, but some of them have but a small output. The leading mines of the district are the following:

The Lick Run Mines.
The Laurel Hill Mine.
W. B. Brooks & Sons' Mines.
C. L. Poston & Co.'s Mine.
The Nelsonville Mining Co.'s Mine.
Johnson Bros. & Patterson's Mine.
The Longstreth Mine (C. & H. C. & I. Co.)
The Brier Hill Mine.
The L. D. Mine.
The Floodwood Mines.
The Hamley Run Mine.

These mines are all located in New York and Dover townships, Athens county, with the exception of one of W. B. Brooks & Sons' mines, which is in Ward township.

From Haydenville to Floodwood the coal has been cut out by the erosive action of the Hocking river. The area from which the coal has disappeared varies between one and two miles in breadth throughout this interval.

Most of the mines named above are on the east or Nelsonville side of the river, but several are worked on the western side. The coal throughout the field is, however, quite uniform. Every large mine will show rooms or sections of slightly lower quality than the rest, but the averages of all of the principal mines agree quite closely with each other. More depends on the care with which the coal is mined and prepared for market than upon the mine from which the coal comes.

The Nelsonville district was the first portion of the Hocking Valley coal field in which mining on a large scale was undertaken, and it consequently has advanced further toward exhaustion than any other district. The territory nearest the town has already lost almost all of its coal. The bad system of mining that prevailed in the earliear days led to much needless loss.

The admirable character of this coal as a domestic and steam fuel is so well known that no detailed statements in regard to it are called for here. Nor will it be necessary to describe all of the mines in detail. One will be taken from the east side of the river and one from the west, and the main statement will be given in connection with these.

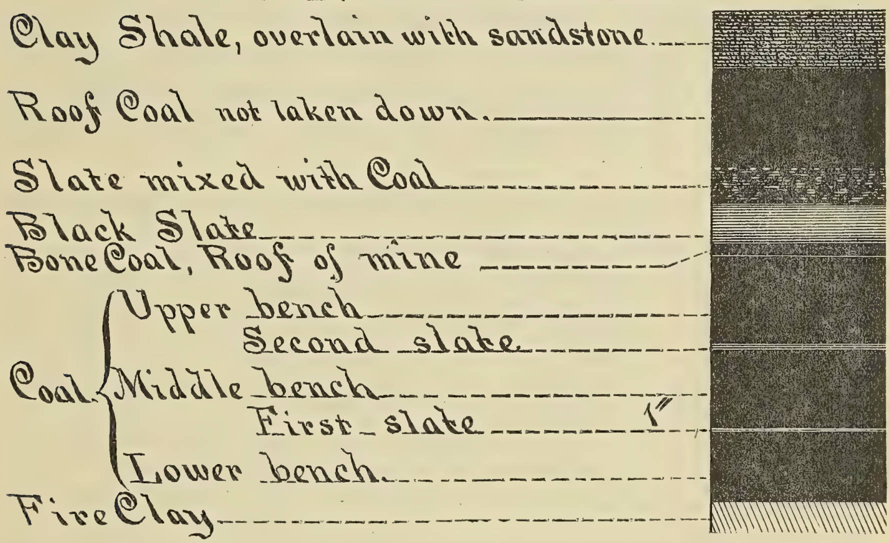
The well-known mines of W. B. Brooks & Son, in Section 19, Ward township, are selected to represent the eastern side, and the new mine of Johnson Brothers and Patterson the western side.

The section and structure of the seam in Brooks's Snake Hollow mine are shown in the appended figure.

The section, as here figured, represents the seam in full and normal development, but it is found in only a part of the mine. The upper portion has been cut away as far down as the bone coal in perhaps half of the territory already worked, especially in the north-western parts of the mine. In a few instances the upper bench of the coal has suffered a little, but it rarely falls below 2 feet. The roof is much better when the full section is found than when the top has been cut away and replaced. In the latter case the shales that come in are slippery and

FIGURE CXV

STRUCTURE OF NELSONVILLE COAL IN THE SNAKE HALLOW MINE OF W. B. BROOKS & SON.



treacherous to some extent, often falling to the sandstone, but the roof that they form is, after all, somewhat better that it looks. In the normal seam the thin layer of bone coal that comes in above the upper bench makes an excellent roof. The coal splits naturally at this point, and the bone coal, with the black slate above it, is strong and unaffected by the air.

As usual in the seam, there is a band of soft coal directly over the second slate. Aside from its friable nature this band is not especially objectionable, but the character of the output would be improved if 2 to 4 inches were split off from the upper bench. When sent out, as it generally is, it mainly turns to slack before it reaches the consumer.

The coal cuts easily. Faces are remarkably bright and regular. The end joints or cutters divide the coal into blocks 8 to 12 inches in thickness. The direction of the face is about 10° east of north.

Irregularities in the coal itself are very rare. A single clay vein in the present workings cuts across 2 entries, in a north-easterly direction, but, as a whole, the coal is undisturbed and regular.

The fire-clay on which the coal rests is unusually thick. It is a

soft, plastic clay, but it makes a good and safe floor when properly drained. If water is allowed to stand in entries, the clay soon softens and rises.

While the normal dip of the seam is maintained, there are local pitches to the northward that confuse the drainage to some extent. The matter of drainage is effected in this mine in an unusual way. Mr. John Wallace, the engineer, has invented and patented an automatic pump, that for simplicity of plan and efficiency of execution, deserves the highest praise. It is in reality a very valuable contribution to mining engineering.

The coal is brought through the front hills of the Hocking Valley which are now mainly exhausted, by a mine locomotive.

The mine is worked on a single entry plan, which has thus far mainly prevailed in the Hocking Valley. The seam lies so high that it is comparatively easy to drive entries through to day and thus a natural circulation is secured, which, though inconstant and somewhat inadequate, obviates the necessity of a thorough-going artificial system of ventilation. The coal is worked altogether on face and ends. Rooms are 24 or 25 feet wide, and 75 to 100 yards deep. Ribs between the rooms are left but 4 feet wide, and not much effort is made to draw them. A little coal is sometimes saved from them, but about 14 per cent. of the seam can be counted as sacrificed in this one item. The entry pillars are about 30 feet thick.

The Butler mining machine is in use in this mine, and gives ample satisfaction. The Company rents the machines to competent and responsible miners, who take a contract to deliver the coal. The contracting miner pays the company 20 cents per ton for the use of the machine, with 70 cents mining rate. He sub-lets the loading and delivery of the coal at 17 cents per ton, and employs two day-hands to work with himself at the machine. The machine miners, under these conditions, find themselves better paid than they would be by the use of pick and drill. The problem of machine mining is considered to be best solved in this way under present conditions of the valley.

The Brooks mine has always been under energetic and efficient management as to amount of coal sent out. Its present normal output is from 50 to 60 cars per day. It has loaded 93 cars in a single day. This record places it well to the front among Ohio mines.

The composition of the coal of the Brooks mine is given below, the 3 benches being sampled and analyzed separately:

W. B. Brooks & Sons' Coal, Section 19, *Ward Township* (*Lord*).

1. Bottom bench.
2. Middle bench.
3. Top bench.
4. Average of the three.

	1.	2.	3.	4.
Moisture	7.24	6.77	5.83	6.61
Volatile combustible matter	34.78	37.31	37.12	36.40
Fixed carbon	56.09	54.18	52.25	54.17
Ash	1.89	1.74	4.80	2.81
Total	100.00	100.00	100.00	99.99
Sulphur	0.54	0.51	0.50	0.52

These are remarkable results for Ohio coals. In particular, the middle bench of the seam shows here its highest quality, but even the top coal, which is the poorest of this seam, as usual, is better than the best coal of many well approved fields. The results are somewhat more favorable than would be obtained from an impartial sampling of the coal from the railroad cars, as more or less slate finds its way into the product, none of which is taken in sampling the seam in the mine.

These statements show with sufficient details the general character of the coal and the methods of mining employed in the Nelsonville field. The seam is seen to be a 3-bench coal, measuring, with its slates, fully 6 feet in thickness, and sometimes yielding 6 feet of clean coal.

It now appears probable that this seam, as worked in the Nelsonville field is, in reality, the original or normal Middle Kittanning seam, here scoring its highest mark, both as to volume and quality. The Hocking Valley supplement, according to this interpretation, lends no value whatever to the field, except in the minor point of giving a good roof to the lower coal.

The coal has been extensively worked at Nelsonville, and in its vicinity, for 30 years. For the last ten years the product of the mines has been large. The front hills are already exhausted, as has been already stated. The mine just described, though shipping its coal by the main line of the Hocking Valley Railroad, belongs, in reality, to the Monday Creek side, the coal being brought through the hill.

The next mine, on the east side of the river, is the Nelsonville Coal Company's mine. It lies almost in the center of the corporation of Nelsonville. The present owners are Lama and Doane. Its output is comparatively small, 6 to 8 cars being about what it can easily and

regularly send out. The coal agrees in general character with the seam as already described.

The mine of Poston and Company, which is next reached, is one of the oldest and best known of the field. Many of the descriptions already given apply to this property. It is, in fact, a piece of the same body of coal as that in which Brooks' mine is opened, but the quality falls below the analyses quoted. The mine has a capacity of about 25 cars per day. It has a long haul for its present production, and makes use of a mine locomotive in going through the hill. An analysis of the coal will be found on a subsequent page.

Longstreth's old mine comes next in order. This property is mainly worked out on the Hocking Valley side, and operations are suspended at the original works. The entries have been driven through to Monday Creek, and a large mine is operating there on the remainder of the coal. This mine is known as the Big Brier Hill Mine, or as No. 31, of the Columbus and Hocking Coal and Iron Company. It has a capacity of about 40 cars per day.

A little above it, in the Monday Creek Valley, is the Little Brier Hill Mine, of Ricketts and Matthews. An analysis of the coal from this mine will be given on a subsequent page.

Returning to the Hocking Valley again, we find the small mine of Hall and Dresback, No. 39, of the Columbus and Hocking Coal and Iron Company, working out a small block of coal belonging to the old Longstreth property. The mine is equipped to produce 6 or 8 tons per day.

In the point of the hill that separates the valleys of the river and Monday Creek, near their junction, is situated the Maple Hill mine of W. A. Shoemaker & Co. It has a capacity of about 25 cars per day.

The coal was mined in this hill for many years before the railroad was built, finding its way to market by the canal. The old workings were wholly lacking in system, and have left the coal in bad shape, as is found by present workings. In addition to this fact, the seam itself is considerably troubled and somewhat reduced at this point. The main entry of the present mine is in faulty coal for several hundred yards, and in the rooms the lower bench is often found reduced to 14 or 15 inches, and the middle bench to less than 2 feet. The seam will not yield more than 5 feet of clean coal on the average. The quality

of the output, however, seems to be kept up fairly well, aside from a considerable increase in sulphur.

The main interruptions come from clay veins, which disturb the coal of a considerable territory in the southern parts of Sections 11 and 17. In fact, an east and west line through this territory leaves the steady and unbroken portions of the seam to the northward.

A little beyond Maple Hill Mine, on the Monday Creek branch of the railroad, the small mine of Juniper Brothers is located. The seam is found here of its normal measure and quality. The capacity of the mine is 10–12 cars daily.

Throughout this field the rider seam of the Hocking Valley supplement is often found, but never mined. It is seldom more than 2 feet thick, and generally much less. It is 2 to 4 feet above the top of the true seam. The composition of the Nelsonville coal will be shown in the table of analyses that follow:

Analyses of Nelsonville Coal. (Lord).

1. Poston & Co.'s Mine. Sampled from seam by C. L. Brown.
2. Little Brier Hill Coal. Lower bench. Sampled by C. L. Brown.
3. Little Brier Hill Coal. Middle bench. Sampled by C. L. Brown.
4. Little Brier Hill Coal. Upper bench. Sampled by C. L. Brown.
5. Little Brier Hill Coal. Average of 2, 3 and 4.
6. Little Brier Hill Coal. Rider seam.

	1.	2.	3.	4.	5.	6.
Moisture	5.73	5.88	5.92	5.12	5.64	3.03
Volatile combustible matter	36.76	37.77	37.59	33.88	36.41	43.75
Fixed carbon	51.99	51.99	53.43	51.23	52.21	40.14
Ash	5.52	4.36	3.06	9.77	5.73	12.48
Total	100.00	100.00	100.00	100.00	99.99	100.00
Sulphur	1.42	1.94	1.14	1.63	1.57	4.86

These figures explain themselves. The chief feature is the increase of sulphur in coming southward from Ward township, and westward from Monday Creek. This element is by no means in excess for Ohio coals, but it is 2 or 3 times as large as is shown in the chief mines of the valley.

On the west side of the river, the following shipping mines are found, viz.:

Lick Run—Approximate capacity, 15–20 cars per day.

Laurel Hill—Approximate capacity, 10 cars per day.

Johnson Brothers and Patterson—50 cars per day.

L. Steenrod's Mine, No. 41, Columbus and Hocking Coal and Iron Company, 15 cars per day.

Haybron Brothers' Mine, No. 39, Columbus and Hocking Coal and Iron Company, 5 cars.

Old Floodwood Mine—B. B. Sheffield.

Hamley's Run Mine.

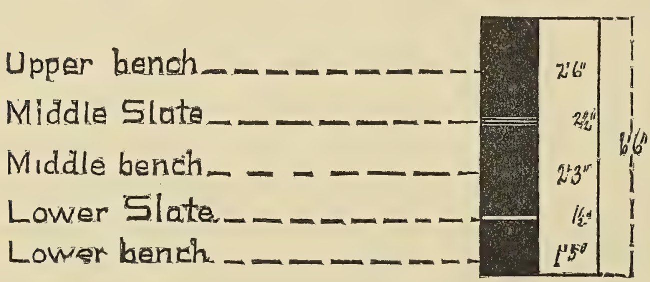
In addition, the New Floodwood Mine, on the east side of the river, is now fully equipped for mining and shipping on the large scale, but as yet it has done but little. It is a part of the property of the late Buchtel Iron Company.

Of the mines in this list, that of Johnson Brothers and Patterson will almost equal the combined capacity of the rest. It has shipped, in fact, 107 cars of coal, containing 1710 tons, in one day. This is the largest amount yet handled by an Ohio mine in a single day.

This mine will be first described. It is located in Section 24, directly opposite Nelsonville, in what is known as Saltwell Hollow.

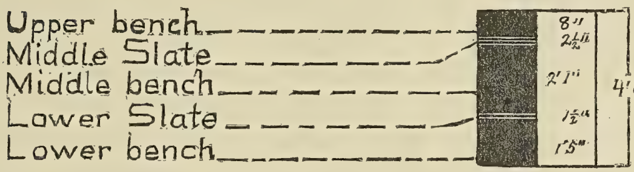
The structure of the coal in the northern portion of the mine is shown below. This represents much the larger part of the area already worked. The later workings, however, are less favorable:

FIGURE CXVI
STRUCTURE OF NELSONVILLE COAL.
JOHNSON BROS. & PATTERSON'S MINE.



In the entries, running south toward Meeker's Run, through the second hill, the seam is lower. The top bench is sometimes entirely cut out, but generally 8 to 10 inches of it are left. This reduces the seam to 3½–4½ feet in thickness. Its structure is shown below:

FIGURE CXVI-A
STRUCTURE OF NELSONVILLE COAL
JOHNSON BROS. & PATTERSON'S MINE.



A like condition exists in the entries running westward. Little of value is found in the seam above the second slate. There is reason to expect that the seam will regain its normal volume before it is followed very far, in either direction, inasmuch as it is known to be of full measure in advance, but the reduction bears hard upon the present mining property. When the seam is thus cut down at the top, its average composition is improved thereby, all of the coal being below the second slate.

This body of coal is more disturbed by clay veins than the coal of most mines of the district, but no single one produces any great drawback or interruption. Its composition is shown in the following analysis. The analysis of Steenrod's coal, the next mine to the south, is also given in the same table:

Analyses of Nelsonville Coal. (*Lord*).

1. Johnson Brothers and Patterson's Mine.
2. Steenrod's Mine, No. 41, Columbus and Hocking Coal and Iron Company, sampled from seam by C. L. Brown.

	1.	2.
Moisture	5.44	5.38
Volatile combustible matter	37.53	37.58
Fixed carbon	51.51	51.21
Ash	5.52	5.83
Total	100.00	100.00
Sulphur	1.23	1.94

These figures show a good coal, fully up to the ordinary type of

the Nelsonville coal, but not reaching quite the degree of excellence that is found in some portions of the valley.

The Steenrod Mine in Section 17, directly opposite the old Longstreth mine, carries in its best portions fully 6 feet of coal, the benches measuring 20, 24 and 26 inches, respectively, from the bottom up, but the quality of the output would be slightly improved if 2 to 4 inches were rejected from the bottom of the upper bench, this being the place of the soft coal so often referred to. A streak of bone coal is often found next to the roof. The rider seam is found in but a small portion of the worked area. Where shown, it is not more than 6 inches thick, and it lies about 2 feet above the upper bench of the main coal. The roof of the mine is best when the rider seam is present. When absent, the roof *appears* very threatening and dangerous, by reason of the "slips" that characterize it, but the masses of shale that are disposed to fall generally come with the coal, and therefore give the miners but little uneasiness. In other words, the roof, even in its poorest phases, is much better than it seems.

The coal is stained for 125 yards from the outcrop, the seam yielding here peacock coal, but this mark is rather an advantage than a disadvantage in market.

On the southern side of this mine also, there is a notable reduction of the coal over quite an area. The entire top bench is lost for 40 or 50 yards of entry, and, in rare distances, the second slate is cut away, leaving the middle bench to be trenched upon. The extensive erosion to which the great seam has been subjected in the Hocking Valley, in comparatively few instances cuts below the second slate. This part of the seam appears to have acquired full strength and hardness early.

The coal of this mine comes out in large blocks, and has a good name in the markets which it reaches.

Two mines that lie north-west of Nelsonville and on the west bank of the river have been omitted from their natural order in this review, viz., Lick Run and Laurel Hill. They are both established in the northern outcrop of the great seam, and thus lie high in the hills. They are located in Sections 33 and 35, York township, respectively. The coal is not at its highest mark in this area, and some unusual disadvantages have attended the working of the first-named of these mines, but with proper facilities for handling the coal, better results are to be

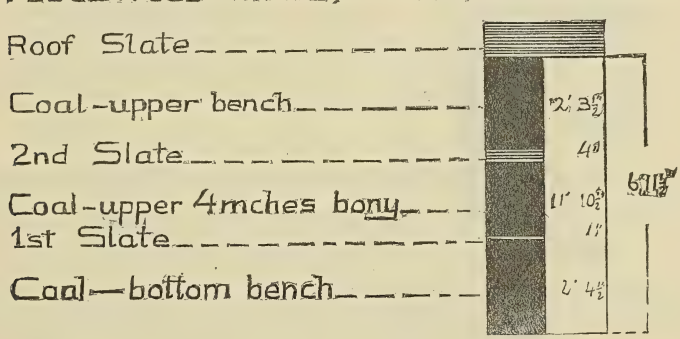
looked for. The Lick Run mine has lately passed into the hands of W. P. Rend & Co., on a long lease.

South of Meeker's Run and west of the river the seam rarely yields more than 5 feet of clean coal, and it is found increasingly liable to trouble in this direction. There are many fine bodies of coal that will give a long and prosperous life to the mines established and to be established in them, but the sandstone is much more apt to descend, and thus reduce and deteriorate the coal than in the northern portions of the field. In the vicinity of Floodwood, on both sides of the river, a good deal of harm has been wrought to the seam in this way, and still large and valuable bodies are intact.

Figure CX, which follows, shows the structure of the coal in the New Floodwood mine on the east side of the river. This mine was opened to supply the furnaces that have lately been built here, but, as they have not been put in blast, a small output has gone forward to the general market. The coal is reached by a shaft of about 30 feet.

FIGURE CX

STRUCTURE OF NELSONVILLE COAL AT HOCKING COAL & IRON CO'S FLOODWOOD MINE, — AT FURNACE.



The structure represented is the average of the measurements in three rooms and one entry, as furnished by Mr. J. H. Mullins, manager. The coal appears to show a different distribution between the two lower benches from that which generally obtains. This mine, as far as worked, has been found subject to considerable irregularities. The coal runs down at the top, through the intrusion of sandstone. The removal of the whole of the top bench is not unusual in the main entry as far as it has been driven. No fault can be found with the

quality of the coal thus far produced. Being derived largely from the two lower benches, it shows itself a strong and excellent fuel.

Hamley's Run mine is located in Section 32, Dover township. It is owned by H. C. Will & Co. The coal here lies about 60 feet below the surface, and is reached by a shaft. In thickness it will average about 5 feet. It suffers considerably from the descent of the sandstone, as does all of the coal of this part of the field. Clay veins are not found here, all of the trouble coming from the roof. In places the coal is cut away to below the second bench, but this happens rarely. The erosion generally terminated before the second slate was reached.

The supplementary seam, as shown in this mine, has a thickness of 14 inches, the lower 6 inches being a bone coal, which makes the roof of the rooms in which the coal is normal. Above the bone there is an 8-inch seam of a coarse and unmarketable coal.

A sulphur band, 1 to 2 inches thick, lies at the bottom of the seam in some parts of the mine. The division of the seam is as follows:

Roof coal—Rider seam, not taken	8	inches.
Bone—Roof of rooms	6	"
Top bench	24	"
Lower 6 inches, rejected, soft, second slate	4	"
Middle bench	24	"
First slate	1	"
Lower bench	10	"
Sulphur band, occasional	2	"
Fire-clay.		

The mine is equipped to send out about 8 to 10 cars per day. The C. H. V. & T. R'y coals its passenger locomotives here. The coal has full size and strength, and is well approved in market.

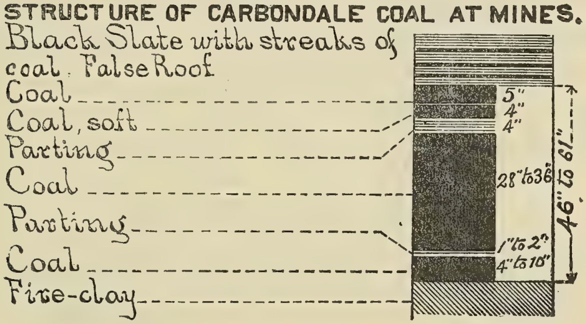
The mines at Salina and Chauncey, that are worked to supply the salt furnaces with which they are connected, agree in all general respects with the mine last described so far as the coal is concerned.

In the south-west corner of York township, and in the adjacent portions of Waterloo, Section 31, the extensive workings of the Carbondale coal are struck. The Marietta and Cincinnati Railroad (now the C. W. & B. R'y) has a branch line running into this field, and the Carbondale mines have been made to yield a very large production for more than 20 years. A number of other mines are also opened in the Carbondale coal in the township, particularly at Mineral City and King's Switch. In an earlier portion of this volume, pages 109, 110,

it has been demonstrated that the Carbondale coal is in reality the Nelsonville seam, reduced to somewhat smaller proportions and somewhat deteriorated in quality, but still maintaining the divisions and general characteristics of the more favored portions. The structure of the Carbondale coal is shown in the appended figure. By examination of the diagram, it will be seen that the main change from the Nelsonville phase consists in the reduction of the lower bench, which is compensated in part by an unusual thickness of the midde bench, bringing the aggregate thickness of the two lower benches up to the normal measure. The upper bench of coal carries the soft coal as usual directly above the second slate, and only a thin piece remains to be split out before the top of the original Middle Kittanning seam is reached. The Hocking Valley supplementary seam here degenerates into a black slate with streaks of coal, a vast amount of fossil wood being carried in its lower portion. In passing over the Hocking Valley field from Sunday Creek to Carbondale, the middle bench is seen to have been increased from 4 to 30 inches, or to even more.

FIGURE CXVIII

STRUCTURE OF CARBONDALE COAL AT MINES.



The composition of the coal, as sampled by Mr. C. N. Brown, and analyzed by Professor Lord, is shown herewith :

Composition of Carbondale Coal (Lord.)

Moisture	5.05
Volatile combustible matter	38.55
Fixed carbon	49.62
Ash	6.78
Total	100.00
Sulphur	2.63

These figures can be recognized as marking the Nelsonville type, but they show an inferior grade, especially in the high percentage of sulphur.

There is good reason to expect somewhat better coal as well as a little more of it, in the territory to the north-east of Carbondale. It is asserted that in the entries running to the eastward in the Carbondale mine, the coal strengthens perceptibly. It is probable that this thickening will be found to consist either in the restoration of the lower bench to its normal measurement in the Hocking Valley, or to an improvement in the quality of the top bench by which it becomes mineable, as at Hamley's Run.

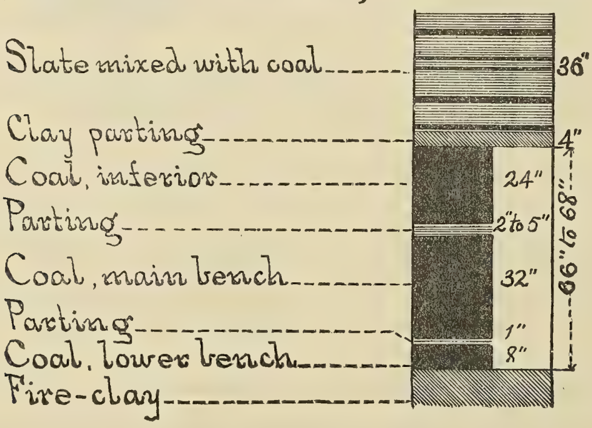
This completes the account of the principal mines of the Hocking Valley in the Middle Kittanning seam of coal (No. 6 of Newberry).

The condition of the seam in Starr township, Hocking county, will also be briefly considered here. There are no shipping mines in Starr, but the thickness and quality of the coal are so often made the subject of inquiry, that the facts that are in hand will be given, to meet as far as they may, such questions as arise.

Quite an area in the eastern part of Starr township is credited upon the map with holding 5 feet or more of coal in this seam. This area is chiefly confined to Sections 1, 2, 3, 4 and 7. Throughout most of it the seam is under heavy cover, and our knowledge of its condition is fragmentary and imperfect. The Lick Run coal is followed

FIGURE CXIX

STRUCTURE OF NELSONVILLE COAL ON FARM OF OLIVER MORGAN, SEC. 1. STARR TP.



to the township line, and a few openings to the westward indicate the continuance of the seam as represented.

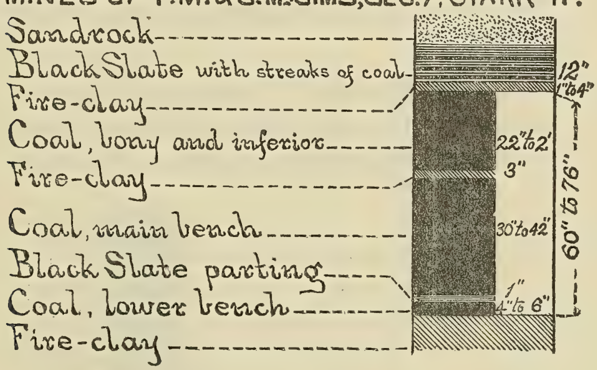
In Section 1, on the farm of Oliver Morgan, the seam shows the structure represented in the figure.

The normal seam is seen to have a thickness of 6½ feet, but it is to be noticed that the upper bench, 2 feet in thickness, is inferior in quality. It does not seem probable that this bench would prove marketable if a shipping bank were to be opened here. The supplementary seam is represented by a worthless alternation of leaves of coal and slate. The seam seems likely to yield 3 to 3½ feet of clean and thoroughly merchantable coal.

Nearly the same state of things is found in Section 7 on the farms of F. M. and S. M. Sims. The structure and character of the Sims coal are indicated in the accompanying figure :

FIGURE CXX

STRUCTURE OF NELSONVILLE COAL AT MINES OF F.M.&S.M.SIMS,SEC.7, STARR TP.



There is probably but little, if any, more of merchantable coal in the seam at this point than in the seam of Carbondale, although the upper bench presents a somewhat better appearance in Starr than it does in Waterloo. Until a coal seam is tested either by thorough sampling and analysis, or by competition in the general market, it is not safe to pronounce upon its quality. The fact that farmers mining, as best they may, a few tons for winter use, take the whole seam, is not a sure indication that the general market will receive it.

There is a somewhat better showing of the seam on Fraction 18, on the Collins farm.

The Upper Freeport Coal in York and Western Dover.

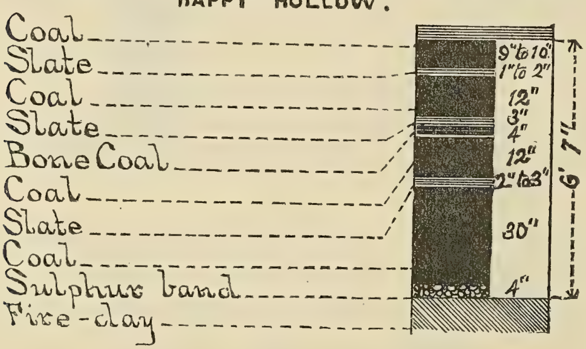
This seam, which is here known as the Bayley's Run coal, or Coal No. 7, has a fine development over a considerable territory in the townships named, and is already worked in three shipping mines.

In Section 35, Dover, and in the adjacent Section 5, of York township, the large mines of the Nelsonville Coal and Coke Company are situated at a point known as Happy Hollow. The seam is here 6 feet in thickness when undisturbed. It lies from 70 to 80 feet above the main coal, the Lower Freeport seam generally occurring in the interval, at a height of 40 to 45 feet above the main coal. The Freeport limestones are finely developed in this region, the upper one lying 15 to 20 feet below its coal. The Buchtel ore belongs in the clay that accompanies and underlies the coal, being about 10 to 15 feet above the limestone.

The coal has proved very steady and regular in a part of the territory worked. In another part, where it was first opened, the bottom was uneven and the coal unstable to such a degree that mining became unprofitable. The structure of the seam, when at its best, is shown below:

FIGURE CXII

STRUCTURE OF UPPER FREEPORT COAL (No 7)
AT MINES OF NELSONVILLE COAL & COKE CO.
HAPPY HOLLOW.



It is to be added, however, that the partings shown here, unlike the partings of the great seam, are inconstant and changeable. In other words, they do not *characterize* the seam. The frequency of shale partings in the Happy Hollow coal makes it somewhat hard to clean properly for market. It is softer than the great seam below it, breaking more easily in handling. Part of this body of coal is under shallow

cover, and is weaker than usual on this account. The working of the lower coal is carried on in the same tract with the workings of the upper seam, the latter workings being kept in advance as far as practicable. No perceptible effect has yet been produced upon the upper seam by the removal of the lower coal.

The coal, as has long been known, is moderately cementing, gathering up its slack into a fairly firm coke. A dozen ovens have been erected here, the only ovens now in operation west of Columbiana county in the State. Only the slack is used in the ovens, and for reasons already given, this is found to be quite impure. The sulphurous character of the seam shows also in the slack, and the coke is so high in this element as to forbid its application in most foundry work. If the best of the seam were used for coking, somewhat better results would be secured. A great improvement would doubtless be effected by washing the slack or coal.

The composition of the coal is shown in the appended analysis, the entire seam being sampled in the mine.

Happy Hollow Coal (*Lord*).

Moisture	5.10
Volatile combustible matter	36.97
Fixed carbon	49.68
Ash	8.25
Total	100.00
Sulphur	2.41

The analyses given of the Bayley's Run coal in the Hocking Valley field show that it has lost a little fixed carbon as it has been followed westward. From Cambridge to the Pennsylvania line, it nowhere contains less than 50 per cent. of this element. The Happy Hollow coal is used almost exclusively as a steam coal.

The Half Moon mine, No. 25 of the C. & H. C. & I. Company, is arranged to handle the coal of both the upper and the lower seams (Nos. 6 and 7) by the same chute. It is located near Akron Furnace. All of the descriptions already given apply without change to this mine. It is one and the same body of coal as that in which the Happy Hollow mines are located. The working of the upper coal is not pressed at present.

There is promise of a valuable field of the Upper Freeport coal in

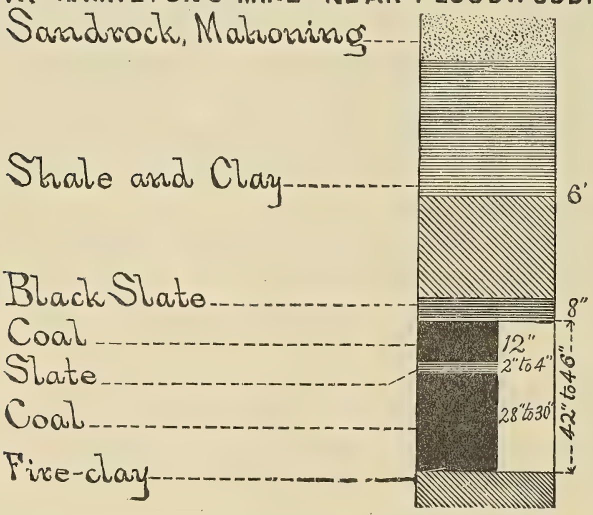
these townships. The great seam at present monopolizes attention and overshadows this upper seam, which would be elsewhere counted an excellent basis for mining.

In Section 8, York township, near Floodwood, a new mine has recently been opened in this seam by the Hamilton Coal Co.

The structure of the seam is shown in the appended figure:

FIGURE CXIV

STRUCTURE OF UPPER FREEPORT COAL (No 7) AT HAMILTON'S MINE NEAR FLOODWOOD.



The measurement was taken before the entry was driven far under the hill, but it fairly represents all of the subsequent workings. The coal mines rather small. An effort is now making to improve the size by using slower powder. The product of the mine is almost exclusively used as a steam coal. The seam now under consideration occurs at very many points throughout the territory that has been traversed. It has occasionally been opened in the small way for farmers' banks, but, as a rule, it can be judged of only by its natural outcrops. While unsteady and uncertain, there is no doubt that it makes a very valuable contribution to the fuel resources of the Hocking Valley.

In Waterloo and Athens township this coal was mined for many years on the line of the Marietta Railroad, where it was known as the DeSteiguer coal. The workings have been abandoned for several years.

The Lower Freeport and also the Lower Kittanning coal are occasionally opened and worked in the smallest way in the Hocking Valley.

Not a mine exists in either, but occasionally for convenience, and oftener from curiosity, the seams have been laid open far enough for a few wagon loads of coal to be obtained, but such openings generally fall in after a little, and no opportunities for examination remain. The best showing of Lower Freeport coal that is known in the field is on the Whitmore farm, Section 6, York township, near Buchtel. The coal is 3 feet thick, and appears to be quite highly cementing in character, more so, at least, than the Upper Freeport seam, which is mined and coked on an adjoining farm.

The Lower Kittanning coal is known to have been worked on a very small scale at several points in Starr township, and at one or two points in York, but not a single locality can be pointed out at which the coal can now be seen.

The "Slate Vein" Coal.

In Starr and Washington townships there is a local supply of some importance, furnished by a coal seam, known as the "Slate Vein." It was designated as Coal No. 3*b*, in Vol. III, page 914. The name comes from the fact that the coal is overlain by 2 feet or more of a rich, fine-grained, fossiliferous black slate. The seam can be well seen in the vicinity of Ilesboro, where it is stripped at a number of points. In its best condition it carries $3\frac{1}{2}$ to 4 feet of coal, contained in two nearly equal benches. Frequently, however, only the lower bench is developed, in which case the coal is but 15 or 20 inches thick, while in place of the upper bench a bed of shale or clay is found.

The black shale that overlies the coal is fossiliferous, containing many distinct impressions of lamellibranch shells and other marine forms. A persistent ledge of sandstone, white and hard, underlies the coal, sometimes being separated from it only by the clay that bears the coal.

The Slate Vein is nearly equally distant from the Lower Mercer limestone below, and the Ferriferous limestone above, both intervals ranging from 40 to 50 feet. The most common measure from it to the Lower Mercer is 45 feet, and to the Ferriferous, 50 feet, but each will reach both of the limits named. At one point, indeed, it comes within 25 feet of the Ferriferous limestone.

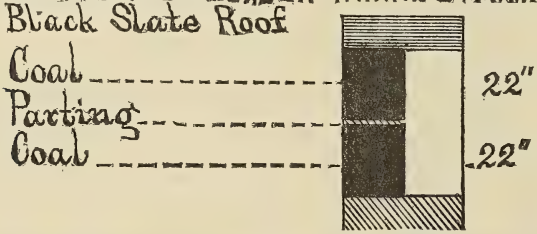
It seems to represent either the Brookville or the Tionesta coal, Nos. 4 or 3*b*, with the probabilities in favor of the former. In this case,

the fossiliferous black slate stands for the Putnam Hill limestone, and the sandstone ledge below is in the place of the Homewood sandstone of the east. The main objection to this identification is the distance of the coal from the Ferriferous limestone. To the north and east, the interval between the Putnam Hill limestone and the Ferriferous (Baird ore) has always been found smaller, but on Monday Creek it rises to 35 feet, and a gain of 15 feet in so considerable a distance is not outside of a reasonable range.

A few facts are subjoined to show the distribution and development of the seam. On Section 31, Washington township, on the farm of G. Niman, the coal shows the structure represented below:

FIGURE CXXVIII

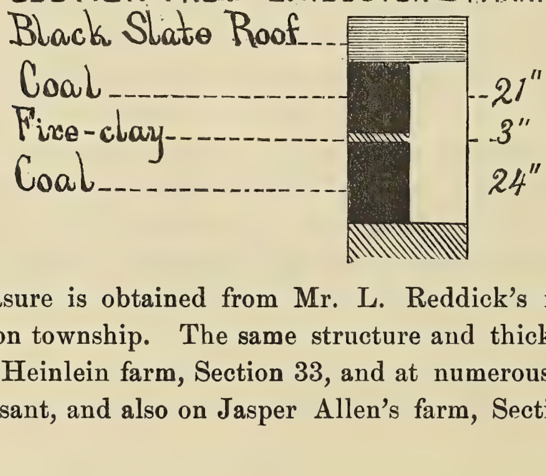
SECTION OF COAL ON NIMAN'S FARM



Another exhibition of the seam is given in the following diagram. These figures stand for the best of the seam, and are not known to represent a wide area. A seam like this is fairly mineable, if persistent. The quality is pronounced good:

FIGURE CXXIX

SECTION FROM L. REDDICK'S FARM



This measure is obtained from Mr. L. Reddick's farm, Section 29, Washington township. The same structure and thickness are also shown on the Heinlein farm, Section 33, and at numerous other points near Mt. Pleasant, and also on Jasper Allen's farm, Section 16. It is

also mined by Jacob Anthony and Eli Johnson, on Section 14, but the upper bench is wanting here, and the coal measures only 18 inches. The seam is also worked on Sections 12 and 13. In fact, the seam is almost universal through western Starr and eastern Washington, passing into Falls and Green. It deserves a more careful investigation than it has yet received, though it is not probable that it will prove a safe basis for any considerable mining operations.

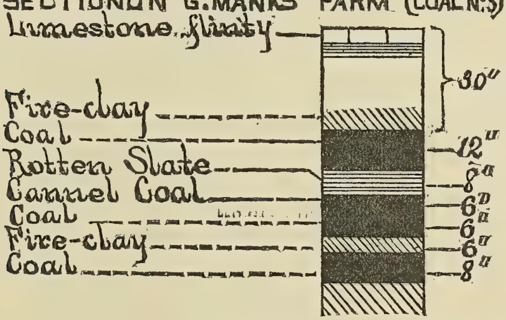
The Mercer Coals.

The two Mercer coals are persistent throughout the field, but the upper coal seldom exceeds 16 inches in thickness. The lower coal is mined, in default of a better seam, through parts of Falls, Washington, and Starr townships. A third seam, known in Washington as the Price coal, seems to belong to this horizon, lying about 20 feet below the limestone. It is probable that this extra seam is of the same age as the Union Furnace block ore. It may be, however, the normal Lower Mercer seam, unusually separated from its limestone. The chief fact that implies another place for it is the presence of a sandstone in the interval in one case.

The normal seam is well shown in the small mine of George W. Manks, on Section 31, Washington.

FIGURE CXXXI

SECTION ON G. MANKS' FARM (COAL No. 3)

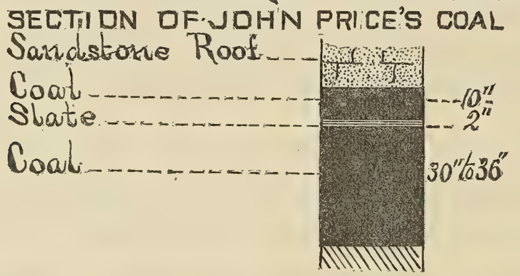


The seam is seen to carry a large amount of foreign matter, and of such a kind as to render steadiness and regularity out of the question. It is not often found in much better condition than this, but its phases are numerous.

The seam, which has been already referred to as an abnormal phase, in some respects, of the Lower Mercer, is known in a few

sections of Washington as the Price Coal. Its structure is shown in the appended figure, which is taken from John Price's farm, Section 32, Washington.

FIGURE CXXXII



The Lower Mercer coal is opened on numerous sections, and the aggregate annual production will reach several thousand tons, perhaps, but the coal could not be mined in competition with any of our ordinary seams.

Below the Mercer limestone, there are two other coal horizons that apparently represent the Quakertown and the Sharon coals of the general scale (Nos. 1 and 2, of Newberry.)

About 45 feet below the Lower Mercer limestone, a coal is often found, and in a few instances it acquires volume enough to tempt a little benching for it on the part of the farmers on whose lands it may occur. It has never been followed many feet under cover. It is known as well by the name of the Mohler coal as by any other, the name being derived from the Mohler farm, in Section 30, Gore township. Its maximum thickness will scarcely exceed 2 feet, and this amount is divided into two or more benches.

The Sharon coal horizon is more persistent, but scarcely more valuable in the district. A few banks are opened in it on the western margin of the coal field, but the seam is unsteady and of little account.

The largest showing is, perhaps, that which is quite widely known as the "eight-foot vein," of Section 4, Washington. On the farm of Nicholas Bowers the seam shows the following structure:

Sandy shale	2 feet 6 inches.
Coal	1 "
Shale and fire-clay	9 "
Coal	2 " 4 inches.
Bone or cannel coal	1 "
Fire-clay.	

There are, of bone and coal together, 4 feet 4 inches in the section, but there is only one bench that is mineable, and this is 2 feet 4 inches thick. Just why 8 feet should have been fixed upon as the popular measure of the seam, it is hard to see. Counting from the bottom of the bone to the top of the rider streak, there are 13 feet in the section, and the coal could have been named the "13-foot seam" by quite as good a right.

The horizon is well marked, even when the coal is wanting, the Maxville limestone (Sub-Carboniferous), or its clay, ore or flint being often found at nearly the same level.

This horizon is found 80 to 120 feet below the Lower Mercer limestone.

As a key to the strata below the Mercer horizon, the following general section can be consulted. It will find its application only on the western margin of the Coal Measures of this region and considerable range in elevations must be allowed for:

Lower Mercer or Blue limestone	100 feet.
Lower Mercer coal, 0—15 feet below limestone	95 "
Union Furnace block ore, extensively benched	80 "
Dresden sandstone—Upper Conoquennessing— Very white and pure, 10–20 feet thick. Contains many impressions of trees, etc. Often replaced by thin stone and shale, in which case one or more coal blossoms occur.	
Mohler Coal—Quakertown coal or Coal No. 2	50 "
Sometimes streaks of ore above and below.	
Massillon sandstone—often heavy.	
Sharon Coal—Coal No. 1	0 "
Sharon conglomerate—sometimes—pebbles coarse.	
Maxville limestone—often flinty, sometimes bears ore. Hard fire-clay—whole series 10 to 20 feet thick.	
Logan sandstone, often conglomeritic, pebbles small and usually flat.	

CHAPTER XVII.

THE COAL SEAMS OF THE LOWER COAL MEASURES OF OHIO—CONTINUED.

MINES OF VINTON AND JACKSON COUNTIES.

BY EDWARD ORTON.

Section I.—Mines of Vinton county.
Section II.—Mines of Jackson Shaft and Wellston Fields. By Andrew Roy.
Section III.—Mines of Jackson County, above the Wellston Coal.

In the map which accompanies this chapter, the following geological features of Vinton and Jackson counties are represented, viz.: (1), the outer margin of the Coal Measures, and (2), the outer margin of the Ferriferous limestone. The extent of the Ferriferous limestone is also indicated in a general way. The first boundary is taken from Newberry's Geological Map of the State; it is not claimed for the second that it represents all of the sinuosities of the real margin, much less that the work of erosion upon the original sheet is properly represented on it. The westernmost points are well located, but there is no map of these counties that furnishes a ready basis for laying down such boundaries in detail, for the reason that the minor drainage streams are not represented. Many consecutive square miles are shown upon the best maps available without a single stream. As the topography depends upon the valleys of erosion, and as the outcrops of the strata are adjusted to the topography, it is evident that an accurate outline of the outcrop of any stratum would involve the making of an accurate map of the drainage system of the region involved. But such an undertaking transcended the limits of the present Survey. The minor details in the distribution of the Ferriferous limestone, particularly in Jackson county, are therefore not to be looked for upon the accompanying map, but the areas are shown within which this leading element is due when the topography admits. It would

have been easy to indicate upon the map many of the valleys from which the formation has been cut out, but inasmuch as the representation could not be extended to all, it was considered to be less misleading to follow the system here employed. The limestone ore of this district has not been worked nearly as extensively as the ore of Lawrence county, and we are accordingly left at a relative disadvantage in representing it.

No question can be raised as to which of the geological elements present deserves to be selected for special representation. The Ferriferous limestone is so conspicuous and valuable by reason of the ore, limestone, coal and clay that belong to it, that it has no competitor for the place of honor on the maps. Moreover, the next horizon in importance, that of the Kittanning coals, is almost as well represented by the limestone boundary as it would be by a boundary devoted to itself especially. The Lower Kittanning coal is but 10 to 25 feet above the limestone, and there are but few outliers and but small areas in these few in which the limestone is found without the coal.

The reduction of the limestone horizon as it is followed northward through Vinton county, and especially in Brown township, is well shown by its disappearance from the map, but it is also to be seen that enough exposures of it remain to hold fast and establish the sections in which it is so important an element. Not less than 8 or 10 outliers are found in the hill-tops of Elk and Madison townships, attesting the former universal presence of the stratum. These outliers it has been possible to map.

The horizon regains its steadiness in Hocking county, and is largely worked there as a source of ore, and to some extent as a source of limestone. The ore north of Vinton county is known as the Baird ore.

The Wellston coal field is also represented in a general way upon the map, but the description of this feature will be reserved for a subsequent section. This seam and also the Jackson shaft coal are so restricted in their distribution, and have so little in common with the field at large, that they will be treated by themselves in a separate section.

Coal Seams of Vinton and Jackson Counties.

The following-named coal seams furnish the present supply of Vinton and Jackson counties:

11. Upper Freeport coal, No. 7, of Newberry.
10. Lower Freeport coal, No. 6*a*, of Newberry.
9. Middle Kittanning coal, No. 6, of Newberry.
8. Lower Kittanning coal, No. 5, of Newberry.
7. Upper Clarion or Scrub Grass coal (not numbered by Newberry, No. 4*a*, or No. 4*b*).
6. Brookville coal, No. 4, of Newberry.
5. Tionesta coal (not numbered by Newberry, No. 3*b*).
4. Upper Mercer coal, No. 3*a*, of Newberry.
3. Lower Mercer coal, No. 3, of Newberry.
2. Quakertown or Wellston coal, No. 2, of Newberry.
1. Sharon or Jackson shaft coal, No. 1, of Newberry.

The two lowermost, which are by far the most important seams of the field, being omitted here, there remain 9 additional coal seams that are found and worked within the counties now to be considered. But four of this number are mined for the general market, viz., the 5th, 6th, 7th and 9th of the list. The remainder are of but very small present value as sources of fuel. The 6th or Brookville seam is a valuable deposit in Hocking and Vinton counties. It is mined for market in Ohio only in Vinton and Stark counties. The 9th of the list is the constant and regular seam that under various names and with varying phases and many changes of fortune has been followed through every county that holds the horizon westward from the Pennsylvania line.

Several attempts have been made to mine the 3rd seam of this list, but they have not proved entirely successful. The attempts are not yet wholly given over. The 7th seam is now brought into market in two or three instances, but it cannot be made to meet existing competition. In other words, the "limestone coal" of these counties cannot, at present, be largely sold in markets to which the Wellston coal finds equal access. The seam, however, supplies a considerable local demand, being the main reliance of many farming neighborhoods for fuel.

The general order of this field has already been discussed in chapter I, page 117, etc., but a few additianal statements as to the different coal seams will be given here, while describing the separate mines of the district.

SECTION I.—MINES OF VINTON COUNTY.

The Jackson Shaft and the Wellston Coals (*Coals Nos.* 1 *and* 2).

The horizons of these coals are abundantly displayed in Vinton county, inasmuch as the boundary of the Coal Measures traverses a large number of its townships. Probably the equivalents of both seams are worked in the smallest way in various country banks, but no one of these openings has acquired as much repute as the so-called Elk Fork coal, of Elk township. It seems to be a very uncertain seam, no trace of it being found in farms adjoining those where its best development occurs. Nothing has been added to our knowledge of it, except a clearer recognition of its unsteadiness and uncertainty, since the date of Professor Andrews's report on Vinton county, report of 1870, page 105. The reports of valuable seams in the lowest measures of Vinton county, where investigated, have not been found to be well supported thus far, but it is highly probable that within the extensive territory in which they are due, some valuable basins will be hereafter discovered. The Elk Fork coal is commonly counted the Wellston seam, inasmuch as it lies about 100 feet below the Lower Mercer limestone.

The Lower Mercer Coal (*Coal No.* 3).

This well-known seam makes a better showing in Vinton county than in any other county of the State, Holmes county alone excepted. At various points in Brown, Madison and Elk townships it has a thickness exceeding 3 feet. In Fraction 19, Brown, the entire seam is said to measure 7 feet. Reference is made to this locality on page 114. In Section 30, Madison, an opening by the side of, and level with the railroad track, shows a thickness of 4 feet for the seam, which is thus divided:

Coal	12 to 14 inches.
Shale parting	12 inches.
Coal with numerous slate seams	24 inches.
Fire-clay.	

Near Zaleski the seam has been quite thoroughly proved, in years past, by the Zaleski Company. It has a thickness of 4 feet or more in many cases, so that it is not volume that is at fault so much as quality. The trouble comes from the numerous shale partings of the coal more than from the coal itself. When well cleaned the coal is often fairly

good, but the slates are not only numerous, but are hard to separate. In addition to this drawback the seam is unsteady. There is no considerable area of it now known that can be mined under present conditions, but the time will doubtless come when its better phases will be worked here. The coal found in a boring at Radcliff's, 137 feet below the Ferriferous limestone, is undoubtedly the Lower Mercer coal. There are many farms in the county in which a little mining has been done in this seam.

The Newland Coal.

If the Newland coal of Elk and Madison townships is the Upper Mercer seam, to which horizon it has been doubtfully referred (page 159), this seam deserves more attention and more exploration than it has yet received. The question existing as to the Newland coal is whether it is the Upper Mercer or the Tionesta coal (No. 3*a*, or No. 3*b*, or *both*.) The latter comes very close to the Upper Mercer limestone in places throughout this region, and it may even prove that the Newland coal results from the union of the two seams, the limestone being represented by a bed of slate or flint that sometimes separates the main benches of the coal.

The Newland coal gets its name from the farm of Benjamin Newland, Section 17, Elk township, where it has long been mined in a small way. It is known in the neighborhood as the 7-foot seam.

The coal at this point lies 38 feet above the *top* of the Lower Mercer limestone, which is found here with the unusual thickness of 6 to 10 feet. The Upper Mercer limestone is found on the same farm, but not in immediate association with the coal. The interval between the limestones, where measured, was found to be 35 feet. So far as this one measurement goes, it renders the reference of the coal to the Tionesta horizon the more probable one. A long and valuable section is found on this farm, the main elements of which are as follows:

Ferriferous limestone (ore and flint).
    Interval, 38 feet.
Kidney ore.
    Interval, 14 feet.
Kidney ore.
    Interval, 43 feet.
Upper Mercer limestone, 6 inches thick.
    Interval, 25 feet.
Lower Mercer limestone, 10 feet thick.
From Lower Mercer to Ferriferous limestone, 130 feet.

This section can be duplicated in the neighborhood, showing a range in total interval of 120 to 140 feet.

The coal on the Newland farm has, in one opening, the structure shown below:

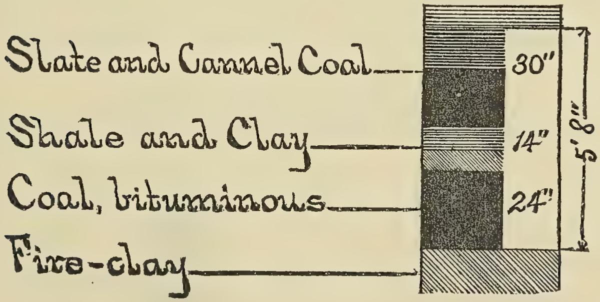
Coal, soft	10	inches.
Clay	5	"
Coal	12	"
Cannel	22	"
Coal	17	"
Fire-clay	66	"

In another opening the structure is as follows:

Bone coal	4	inches.
Coal	12	"
Clay and slate	6	"
Coal	16	"
Cannel coal	15	"
Coal	9	"
Coal	8	"
Total	70	inches.

At one other opening of the seam in the same neighborhood the structure is as follows:

FIGURE CXXVI
STRUCTURE OF NEWLAND COAL NEAR McARTHUR.



On the lands of the Zaleski Company, Section 35, Madison, near the north line of a tract of land owned by Eden Moore, a recent

opening made by W. W. Poston shows the following structure of this coal:

Shale roof, 8–10 feet seam.		
Coal	7	inches.
Black slate	3	"
Coal, good quality	10	"
Fire-clay and bone	6	"
Coal	10	"
Parting, thin.		
Coal	12	"
Clay, holding seam of flint	6	"
Coal, bottom bench	10	"
Fire-clay	—	
Entire thickness of seam	64	"
Entire thickness of coal	49	"
Available coal	39	" in 4 benches.

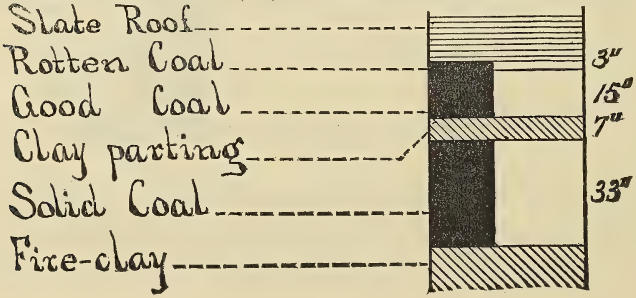
In a ravine a few hundred yards east of this exposure, the seam, as opened, shows much less volume. The position of the coal is from 30 to 40 ft. above the Lower Mercer limestone, which is universal throughout the region. The second bench appears to be of excellent quality. The remainder seems somewhat long-grained and coarse, but quality cannot be properly judged from this mere outcrop.

On the Bryson farm, on Wheelabout, south of Zaleski, the Lower Mercer coal is shown in the creek banks with a thickness of 4 feet.' It is covered by calcareous, fossiliferous shale. The Tionesta coal, now under discussion, is found here 40 to 44 feet above the lower coal, also showing a thickness of about 4 feet. The Brookville coal is also found at its proper level, about 20 feet above the Tionesta.

On the land of Mr. H. R. Demming, S. W. ¼ Section 23, Madison, the same seam is again found in excellent development. The structure is shown in the appended figure:

FIGURE CXXVII

SECTION OF H.R.DEMMINGS COAL.



Minor partings would doubtless be revealed by extended workings. It is claimed that the 3 inches of rotten coal at the top of the seam become good under the hill. The seam lies near the level of the creek at this point.

The seam shows but little sulphur, and is said to burn with a considerable amount of very light ash, which is white in color. Cannel is often found in the seam, replacing the bituminous coal in part. To the southward the cannel becomes the characteristic element.

The Newland coal, as now described, occupies a considerable area in Vinton county. It has not been followed far under cover at any point, except at Vinton Furnace, where it was mined quite extensively a few years ago.

The outcrops do not indicate a very steady seam, but there is certainly a valuable body of fuel at this level that will, at some time, repay development. The place of this seam can be easily fixed by reference to the lower blue limestone. The coal is about 40 feet above this well-known horizon.

The Winters Coal, or the Flint Vein.

Under these designations, a valuable body of the Brookville coal, No. 4 of Newberry, is known and worked in Elk, Swan, Madison and Clinton townships of Vinton county.

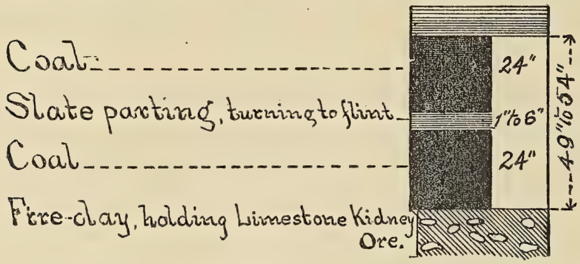
The former name is derived from the name of the owner of the farm, one mile south-west of McArthur, which holds the largest workings of this seam. The second name is derived from the fact that at a number of points east of McArthur, a seam of flint is contained between the benches of the coal. The place of this seam in the geological column is at 35 to 40 feet below the Ferriferous limestone. The limits will probably be found at 30 and 50 feet, respectively.

The quality of the coal probably varies a good deal in different mines. At the Winters mine, near McArthur, the coal is a bright, open-burning coal, rather high in sulphur, and yielding a moderate amount of purple ash, but it is in all respects a desirable domestic and steam coal.

The section of the seam at this point is shown in the following figure.

FIGURE CXXV

STRUCTURE OF WINTER'S COAL, McARTHUR.

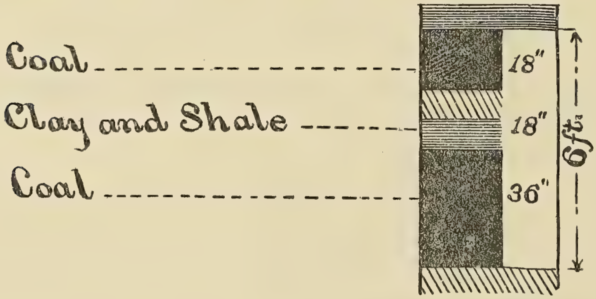


This structure is maintained fairly well through the quite extensive workings of the mine, which has been wrought for many years as the main reliance of the village of McArthur.

It is the same seam that is worked in a small way on the farm of S. H. Trimmer, Section 32, Elk, the structure of which, as reported by David Trimmer, is shown below. The bank is not now open.

FIGURE CXXXIV

STRUCTURE OF TRIMMERS COAL.



This coal lies 65 to 70 feet above the Lower Mercer limestone, a somewhat shorter measure than is to be expected.

To the same horizon is probably to be referred the coal on C. Morehead's farm, in Section 26, Swan township. Its structure is indicated in the figure appended.

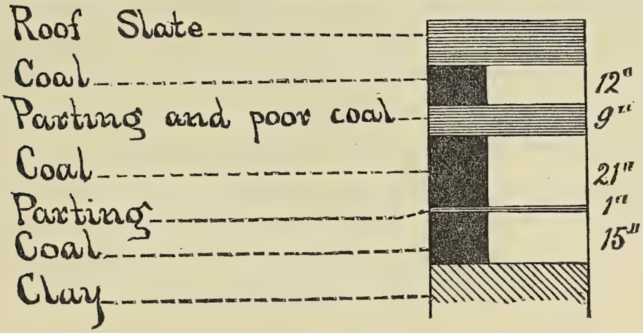
This coal appears well, and is well thought of in the neighborhood that it supplies.

In addition to the mines already given, many others of equal rank might be named throughout the territory under consideration. There is but one shipping mine in this seam in the district, and indeed in

Southern Ohio. It is the lower mine of the Zaleski Company, and it will be described in a subsequent paragraph.

FIGURE CXXIV

SECTION OF C. MOORHEAD'S COAL.



On Mr. H. R. Demming's land, Section 23, Madison, the coal shows a thickness of 58 inches.

The seam has been worked at many points south of Zaleski. To it must be referred the coal mined by Dubler, Scott, McLaughlin, Bowen, and also the coal mined at Prattsville. The seam is everywhere covered throughout this region by a massive showing of the Hecla sandstone which separates this horizon from the Ferriferous limestone horizon.

It is also without question the Eagle Tunnel coal, to which various names have been heretofore assigned. The top of the coal is 36 feet below the Ferriferous limestone, and between the two is found the Hecla sandstone.

The Limestone Coal.

Under this designation the most reliable and serviceable coal for local supply of Vinton and Jackson counties is known. It lies below the Ferriferous limestone, generally immediately beneath it, but sometimes separated by as much as 15 or even 18 feet of shale and clay. A cover of shale is of great advantage to the coal.

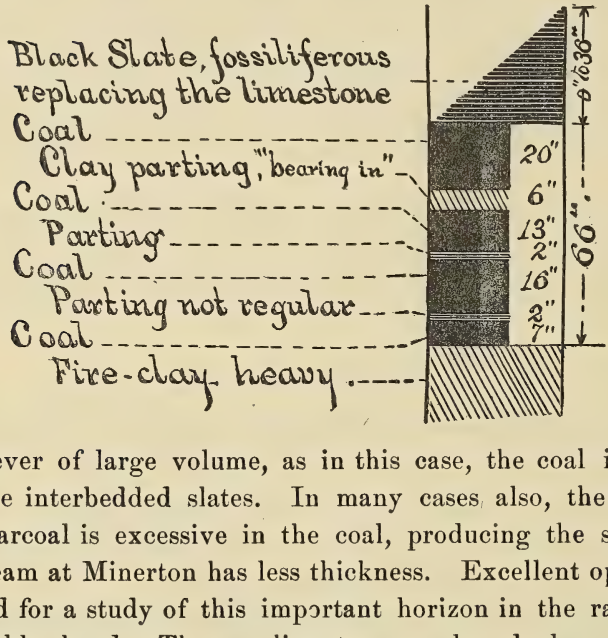
This position marks it as the Upper Clarion or Scrub Grass coal of the Pennsylvania series. By many who have sought to apply Newberry's scale of numbers to Southern Ohio, it has been counted Coal No. 4, but this designation is seen to be inadmissible, inasmuch as the Brookville or Putnam Hill limestone coal lies 20 to 40 feet below it. If these numbers are to be adhered to, the coal would be known as

4*a* or 4*b*, according as one or two coals are referred to the Clarion horizon.

The limestone coal ranges, as a rule, between 3 and 4 feet in thickness, but sometimes rises to 6 or 7 feet. It is bright and handsome, high in sulphur and moderate in ash. In the country banks where only the outcrop is worked, the coal mines small. Probably it will hold this characteristic under deep cover. There are a few small shipping banks in this seam on the line of the Ohio and West Virginia road, one near Hawk's Station, and others at and near Minerton.

The first of these supplies the locomotive of the road with coal; the others ship a moderate amount southward into the coalless region traversed by the road. The seam makes its best appearance at the first-named point, as is shown in the appended figure:

FIGURE CXXXV
STRUCTURE OF LIMESTONE COAL AT HAWK'S STATION.



Wherever of large volume, as in this case, the coal is rendered dirty by the interbedded slates. In many cases also, the amount of mineral charcoal is excessive in the coal, producing the same result.

The seam at Minerton has less thickness. Excellent opportunities are afforded for a study of this important horizon in the railroad cuts in this neighborhood. The ore, limestone, coal and clay, all of them of economic value and interest, are shown in full-faced sections. The coal is seen to be unsteady when it has the limestone for a cover. This coal seam extends from about the middle line of sections of Elk and Madison, southward to Lawrence county. The volume is amply sufficient

to repay working in a large part of the territory, but it has the present disadvantage of being obliged to compete with the Wellston coal in market, a test of value that but few coals of the State can meet successfully. It is no wonder, therefore, that the present use of the limestone coal is mainly limited to the home supply of farmers and to locomotive use, but the area of the coal is large, the seam is of good thickness, its fire-clay gives promise of great value in some places, and, all things taken into account, it can safely be asserted that this seam will prove a large and lasting source of wealth to Vinton county. Its development will be delayed until the choicer coals, that are now available at no greater expense for mining, begin to grow scarce.

The Lower Kittanning Coal (No. 5).

This seam is almost everywhere present in its own place in the field, but its thickness generally falls below 2 feet, and no single instance is now recalled in which it is worked in Vinton county, even in the smallest way. It is found in many of the heavier benchings of the limestone ore, its place ranging from 10 to 20 feet above the Ferriferous limestone.

The Middle Kittanning Coal (No. 6).

Though lacking the importance that it possesses in the Hocking Valley, this wide-spread coal seam displays the same characteristics in Vinton county that give to it its value elsewhere, viz., steadiness and good quality. It enters Vinton county from Waterloo township under the name of the Carbondale or Mineral City coal. It has been largely mined at King's Switch and at Ingham's, on the county line, and also at Moonville. It is still worked at these points, but the front hills have been mainly mined out along the railroad. The main body of the coal that is tributary to this outlet is untouched, but the hand-to-mouth policy which these small mines have always been obliged to adopt has placed future working at some disadvantage.

The seam can be followed with unmistakable distinctness and indisputable identity from Mineral City, where it is found at the level of the railroad, slowly rising to the westward and southward, until it reaches the tops of the hills for its final outcrop in the north-east corner of Elk township. At Mineral City, as already stated, it is level with the railroad, or, in places, 8 to 10 feet above; at the tunnel, it is 17 feet above; at King's, 19 feet; at Ingham's, 52 feet; at Moonville, 73

feet; at Hope Station, 130 feet, and about the same at Zaleski, this place lying nearly in the direction of the strike from Hope Station. These stations are at approximately the same level, viz., 150 feet above Lake Erie.

The section of the coal at Moonville covers fairly well all of these mines. It is as follows:

Bone coal	—	
Clay	4	inches.
Coal	24–28	"
Parting	2	"
Coal	5–6	"

The Zaleski Mines.

The only important mines in Vinton county are the two mines of the Zaleski company. They are located in Section 36, Madison. The Middle Kittanning, or Carbondale, or Nelsonville seam, has been mined here for many years on quite a large scale, and a considerable acreage has been exhausted. The body of coal now opened in this seam is fairly represented in the following figures:

FIGURE CXXII

SECTION OF COAL AT ZALESKI MINE.

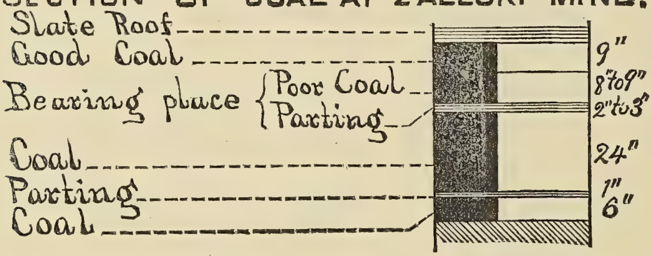
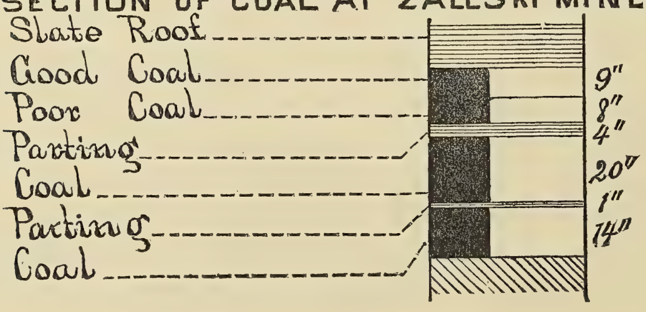


FIGURE CXXIII

SECTION OF COAL AT ZALESKI MINE.

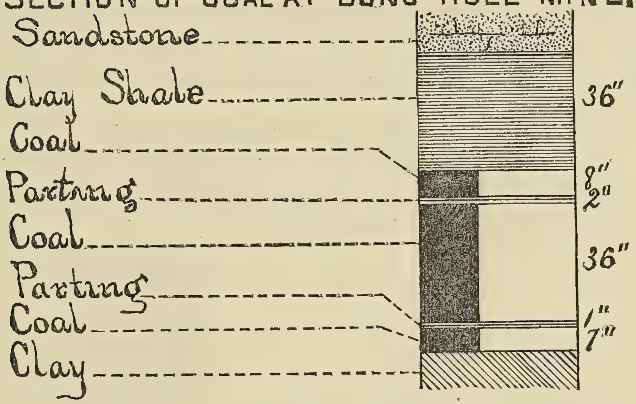


The close agreement in the structure of the seam at Zaleski with its structure in the Hocking Valley field is apparent. Here, as in the last-named field, the seam is made of 3 benches. The slates have the same thickness and character, and the same layer of poor coal is found directly above the second slate as in the Hocking Valley. In fact, the whole of the upper bench is generally rejected, as it is to the eastward of the Hocking Valley.

The bottom bench varies in thickness, ranging from 6 to 14 inches. In some parts of the company's lands, the coal shows somewhat different proportions, as at the Coalmont Works, now abandoned. The structure at this point is shown herewith :

FIGURE CXXI

SECTION OF COAL AT BUNG HOLE MINE.



The coal mines in medium-sized blocks, and is of fair quality. It is used mainly for steam production on the line of the C. W. and B. R'y. A large acreage still remains to the company.

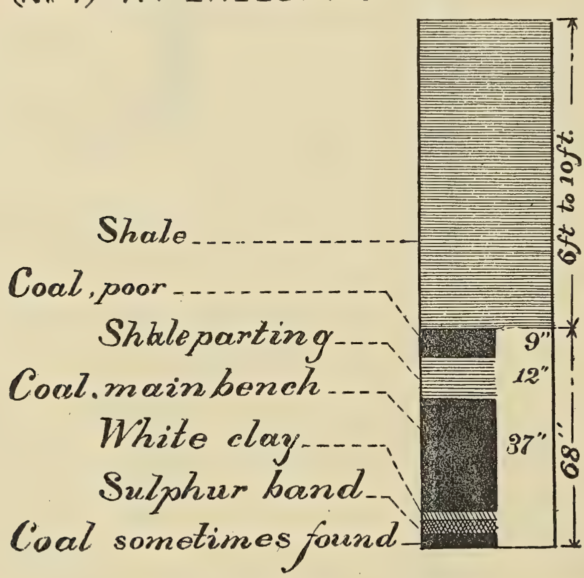
One peculiar fact in connection with this seam may be noted here. In the Report of Progress for 1870, page 78, Professor Andrews gives an account of a quartzite boulder, found partly imbedded in the Zaleski coal. The boulder was worn and smoothed by friction before it came into the coal. It now appears that such boulders are not infrequently met in and immediately above the coal. The bank boss, Thomas Watkins, informs me that he has in a few cases found a number together, sometimes 8 or 10 in the coal, and that single ones are often found. One of these, presented to the Survey, proves to be like the one described by Professor Andrews, a gray quartzite, compact and firm, and well polished externally, as if by glacial action. Some of them are

found entirely bedded in the coal, but more occur in the shales immediately above the coal, but so close that they come down when the coal is taken. Mention has already been made of the large boulder found in the Manly mine at Shawnee, immediately above the second slate. This specimen is also a metamorphic sandstone or quartzite.

Boulders of the same sort are also found in the Carbondale coal. They are not known to occur in any other Ohio seam but the Middle Kittanning. This anomalous characteristic comes in to re-enforce the disputed identity of the Nelsonville and Carbondale coals.

In connection with this mine, another seam is worked, as has been indicated on a previous page. This is the only point south of Stark county where the Brookville coal, Newberry's original No. 4, is worked in a shipping mine. The seam has already been described as it is found in Vinton county. In volume and general structure, the Zaleski mine agrees fairly well with the Deming coal, figured on page 998. The structure of the Zaleski Company's seam is as follows:

FIGURE CXXXVI
STRUCTURE OF BROOKVILLE COAL (No. 4) AT ZALESKI MINE



☞ The coal is not mined below the white clay parting, and, in fact, it is not often that any coal is found below.

The coal is hard to cut, has great strength, mines large, and bears stocking remarkably well. It is not a clean coal, is quite high in ash and sulphur, but it burns well, and is even preferred for locomotive use to the upper seam. The residents of the village also prefer it for domestic use, it is said. For shipment on the road, the two seams are supposed to be mined in equal proportions, both coals being delivered over the same chute. Though thicker than the upper seam, it is harder for the miner to make wages in it. The average output will not probably exceed 2 tons to the miner. The price for mining for both seams is 5 cents in advance of Nelsonville prices. The number of miners in the company's employ exceed 100.

The company has now been mining this seam in the large way for 7 years, and its entries have been advanced to great distances under the hills, the coal proving mineable wherever followed. It is a little unsteady in thickness, the roof shales coming down in rolls into the coal, after the fashion of sandstone horsebacks. Where the roof is thus irregular, it naturally becomes dangerous. Several deaths have resulted in this mine from falls of slate.

The clay beneath this seam has large volume, and presents a very favorable appearance. There are also other horizons in this neighborhood that promise an abundance of good clay for all common uses.

The Lower Freeport Coal (*No.* 6*a*).

This seam is found in good development in Vinton county. In fact, it often has considerably greater volume than the seam below it, and has frequently been mistaken for it. In Volume III, page 918, it was described and named as the Hamden Furnace coal. Nothing need be added to the statements there given, inasmuch as no further developments have since been made. The seam has a thickness of 3 feet 8 inches in the vicinity of Hamden Furnace, and it lies about 60 feet above the Ferriferous limestone.

The Upper Freeport Coal (*No.* 7).

This well-known and well-marked horizon is conspicuous enough in Vinton county by reason of its limestone and clay, but no single locality is now recalled in which the coal is mined.

Summary.

The coal supply of Vinton county is peculiar in this respect, viz., that it is largely derived from seams that are seldom worked or workable elsewhere. The Tionesta, Brookville and Clarion (Upper) coals have greater volume than any other seams of the county, while of the Kittanning and Freeport coals, though all are present, but one is mined to any extent. This one yields but little more than 3 feet of marketable coal, but it is characterized by persistency and steadiness, as well as by good quality, and therefore becomes a safe basis of large mining enterprises.

Mines of Jackson County.

It is to be regretted that time has not sufficed for working out the lowermost 200 feet of the coal measures of Southern Ohio, and particularly of Jackson county, in such a way that clear and satisfactory statements could be made as to the order of the geological elements of economic interest comprised in this part of the scale. Although a good deal of work has been done in the district since the date of Professor Andrews's report upon it in 1870, many of the questions unsettled at that time remain unsettled still. What is required is a few weeks' work carried on in a methodical way, and with the aid of instrumental measurements upon the lower coals of the county. Until this is done, it is scarcely worth while to advance statements upon the disputed points which, resting largely on individual judgment, can be offset by the different conclusions of other observers.

These lower coals constitute the chief element in the mineral wealth of the county, at the present time, and their superior development here gives to Jackson county an enviable pre-eminence among the Coal Measure counties of this part of the State.

Almost all of those whose judgment in regard to the question is entitled to respect, consider the Jackson Shaft coal and the Wellston coal as two distinct seams, but now and then an intelligent person is found who still maintains the older view, that the two coals belong to the same horizon.

There is, of course, no instance known in which typical and universally accepted representatives of these coals are found in the same vertical section, for in such a case the question could not be raised, but a few localities can be pointed out in which the fields

are brought into close proximity. Where the Wellston or Hill coal approaches closest to Jackson Court House, the horizontal distance between the fields is small, but it is unfortunately too large to render the measurement of the vertical interval that has been deduced from the facts as here shown an authoritative one.

One of the most anomalous series of measurements is obtained a mile or two directly east of Jackson Court House. The measurements which follow were made by Mr. Brown, with a spirit level.

On lot 66, Lick township, on the land of Ambrose Scott, a hole was drilled to the Shaft coal, which was found at a depth of 110 feet. This puts it at about the same depth with the coal in adjacent mines of the Jackson Shaft coal field. On the same lot, there are extensive developments of the Lower Mercer limestone. It has been quarried largely here for furnace flux. It is crowded with fossils, and is in all respects thoroughly characteristic. Moreover, the upper members of the series appear in their appropriate places in the hills above.

The distances from the Shaft coal to the Lower Mercer limestone on this lot are 138 and 142 feet in two separate measurements. The Wellston is found in several instances in its own field 120 feet below the same limestone, and thus it appears that the Shaft coal, in an unmistakable occurrence of it, is but 20 feet from the possible horizon of the Wellston coal.

In Section 25, Jackson township, a coal seam has been opened and worked on the land of J. Wilson Case, while almost directly above it, at an interval of about 125 feet, an unequivocal deposit of the Wellston or Hill seam has been quite largely worked on the Spanknebel farm. The identity of the lower seam with the Shaft coal would not, perhaps, be acknowledged by all.

The Shaft coal generally rests upon a conglomerate, pronounced and coarse, but the seam is everywhere covered also by a conglomerate sandstone, in which good sized pebbles, ½ inch in diameter, are often found. Occasionally the upper conglomerate is as coarse as the lower.

The several conglomerates that occur in this general field are in fact one source of the confusion that prevails as to the true order. The Waverly conglomerate is in strong force within this district. There are, besides, the conglomerate below, and the one above the Jackson Shaft coal. As has been abundantly proved, the Carboniferous

Conglomerate can no longer be counted an undivided stratum, but it is rather a complex and much varied formation. There is no single stratum of pebble rock in the State that has any longer a right to be called "the Conglomerate".

But there seems no good reason to call in question the assertion that as the Shaft coal lies below, the Hill coal is above the conglomerate sandstone already named.

The conglomerates that enclose the Jackson shaft coal answer well for the Sharon and Massillon (Conoquennessing) divisions respectively of the great Conglomerate formation of the Pennsylvania scale.

In my report upon the Hanging Rock district in 1877, Vol. III, page 885, a mischievous and confusing error appears in all of the sections involving this part of the scale. The Jackson Shaft coal and the Wellston coal are represented as lying below the Maxville limestone. The real order is given in the preceding statement.

Counting from the Lower Mercer limestone, which is the one constant and reliable stratum through the field, the Wellston coal is about 110 to 120 feet below it in the scale. The Jackson Shaft coal may be provisionally counted as about 75 to 100 feet below the Wellston coal. Larger and smaller measures than these are often found. Counting from the nearest exposures of the Hill coal to the floor of the mines under Jackson Court House, an interval of 175 feet has been deduced, but as has been said, the distance is too great between the exposures to make the measurement a safe one. One mile beyond Jackson, the interval from an unquestioned body of the Shaft seam found in a drill-hole on the land of Ambrose L. Scott, to the blue limestone (Lower Mercer) is but 140 feet, or within 20 or 30 feet of the place of the Wellston coal, but this is certainly abnormal and unusual.

There is, fortunately, much greater certainty as to the order above the Wellston coal. The leading horizons of the Lower Coal Measures are easily identified in the main throughout the county.

The mining interests and present development of the Jackson Shaft and the Wellston coal fields are well treated in the following section, prepared for this chapter by Hon. Andrew Roy, late State Inspector of Mines. He has confined his description to the basin already developed. Others are known and worked in a small way, and if made accessible by railroads, their coals may become valuable. Prominent among these outlying fields is the Hamilton township basin,

about which much has been written in earlier reports. There is no doubt that a thin seam, seldom exceeding 30 inches in thickness, occupies several thousand acres in this township, possessing as much steadiness as is to be looked for at this horizon. Analysis does not entirely confirm the claims that have been made for the Gilliland coal. As sampled by Mr. Brown and analyzed by Professor Lord, it shows the following constitution. It may be added that the appearance of the coal corresponds in every way to these results:

Gilliland or Canter Coal—Jackson Township (Lord).

Moisture	7.04
Volatile combustible matter	37.89
Fixed carbon	44.09
Ash	10.98
Total	100.00
Sulphur	1.19

A general outline of the Wellston coal field is given in the map that accompanies this chapter, but the sinuosities and wants of the field, due to erosion, are not represented in this outline. The map is designed to show the limits within which all the fairly workable portions of the seam, so far as known, are included, but it must be distinctly understood that the seam is not present in all of the area devoted to it upon the map, and also that it may be psesent in areas where not represented.

SECTION II.—THE JACKSON SHAFT COAL, AND THE WELLSTON COAL FIELDS.

By Andrew Roy.

The Jackson Shaft Coal Field.

The Jackson Shaft coal is the lower bed of the State series. It is not so persistent a seam as those lying above it, but it is widely and favorably known as a furnace coal of great value. It lies in basins or troughs of somewhat limited extent, which seem to have been scooped out of the conglomerate rock and underlying Cuyahoga shale anterior to the deposition of the carboniferous accumulation from which the coal is derived.

This coal is found in its best development in and around the village of Jackson, 40 to 90 feet below the surface. It was discovered in 1863

by a party of drillers who were boring for salt. A local shaft was put down to test the thickness and quality of the coal. It proved to be 4 feet thick, to belong to the dry-burning family of coals, and it soon attracted the attention of capitalists, among whom was the late Gov. David Tod, of Brier Hill, from whose farm the famous Brier Hill coal of the Mahoning Valley derives its name. Mr. A. S. Kyle, of Youngstown, was one of the first to pronounce favorably upon the iron-making qualities of this coal.

The Jackson Shaft coal extends through portions of Lick, Coal, Liberty, Scioto and Hamilton townships, in an irregular line, for a distance of 15 or 16 miles, its width varying from ½ mile to 4 or 5 miles. It is disposed on a very irregular floor, and is frequently wanting where it is due. It is met above water level in each of the above townships, but is nowhere mined with vigor, except in the township of Lick, in and around the village of Jackson, the county seat.

There are 6 mines in operation in Jackson, all shafts or slopes, varying from 40 to 90 feet in depth. The coal varies from 3 to 4 feet in thickness, and is mainly used in the blast furnaces of the district. Four of the mines have blast furnaces erected in connection with the shafts, and the coal from two of these mines is delivered directly from the shaft into the furnace stock-house. Two mines rely exclusively on shipping for trade. The following are the names of the mines, together with the names of the operators of the same:

Name of Mine.	*Name of Company.*
Star Shaft	Star Furnace Co.
Huron Shaft	Huron Furnace Co.
Tropic Shaft	Tropic Iron Co.
Globe Slope	Globe Iron Co.
Kyle Slope	Kyle, Shotts & Co.
Eureka Shaft	J. A. Long & Co.

The four blast furnaces at Jackson, which draw their fuel from the Jackson Shaft coal, are:

The Star Furnace, supplied from the Star shaft.
The Huron Furnace, supplied from the Huron shaft.
The Fulton Furnace, supplied from the Globe slope.
The Tropic Furnace, supplied from the Tropic shaft.

The Kyle slope and Eureka shaft ship along the line of the Ohio Southern Railroad, reaching out to Toledo, Dayton, Springfield and

other markets. J. A. Long & Co. also send part of the product of their mine, the Eureka, to Ironton, for furnace use.

The first furnace built at Jackson, called the "Orange," was erected in 1863. This furnace has not been in blast during the past 10 years, but is still standing.

The Star Furnace, which was erected in 1866, is one of the most successful of the county. Last year it made a fraction less than 7,000 tons of metal, the daily product of the furnace, when running, being about 21 tons. The average amount of coal used daily was 1,460 bushels, or 58 and $\frac{10}{25}$ tons, besides about $\frac{1}{3}$ of Connellsville coke. This represents the daily output of screened coal of the mine, none being shipped to market.

The Star shaft is 50 feet deep; the coal varies from 3 to 4 feet in height, receding below 3 feet on the hills in the mine. The coal is a homogeneous mass. The mine makes a little fire-damp, and has done so ever since it was opened.

Owing to the irregular floor of the coal seam, systematic mining cannot always be followed, the hills and hollows encountered perplexing the mining engineer. Four pumps are used in the Star mine to drain the workings of water, the aggregate capacity of which is 500 gallons per minute, and they are all run day and night. The size of the shaft is 8x16 feet, divided into three compartments, two for hoisting and one for pumping and for the ingress and egress of the miners in case of accident.

The Tropic mine of the Tropic Iron Co. was formerly located along side the blast furnace, but in December, 1879, the workings were inundated with water, the roof having given way in a room driven directly under Salt Creek. The water was pumped out, and the fallen area filled with clay and furnace cinder. In 1880 the roof again gave way under Salt Creek, and the workings were again filled up. The mine was a second time pumped dry, and the course of the creek changed, but the proprietors, dreading accident, abandoned the workings altogether in 1882, and located a new shaft $\frac{3}{4}$ of a mile east from dangerous excavation. The Tropic Iron Co., in thus voluntarily abandoning a dangerous mine rather than run the risk of sacrificing human life by an inundation of water, is deserving of special mention. Such disinterestedness is rare indeed.

This new shaft is 93 feet deep. The workings make fire-damp,

though not copiously. The coal is of the same quality and thickness as that of the Star mine, and the floor promises to be equally irregular. This mine also discharges a little fire-damp.

A switch has been built to the new shaft from the Horse Creek branch of the Ohio Southern Railroad, and the mine and furnace are thus connected by railway.

Raw coal is used in the Tropic Furnace in the reduction of ore, 4 tons of coal being required on an average for every ton of iron made. This mine produces coal for the use of the furnace only, the daily product of the mine being 70 tons on the average.

The Fulton Furnace, erected in 1868, is owned by the Globe Iron Company, and receives its supply of coal from the Globe slope, situate half a mile distant. This slope, which was sunk in 1865, had a blast furnace built in connection with the mine, but in 1876 the furnace was burned down and was never rebuilt, and the output of the mine has ever since been used for the supply of the Fulton furnace. The coal is hauled from the mine to the furnace by teams. None of the coal is shipped.

The workings of the Globe mine are irregularly laid out, owing to the depressions and hills which forbid the adoption of symmetrical or systematic plans. The coal falls below three feet on the hills, and recedes to 4 feet in the swamp of the mine.

The Huron shaft, which was sunk in 1875, supplies the Huron furnace with fuel. The furnace and shaft were finished at the same time; the depth of the shaft is 70 feet; the coal is of the same general quality and thickness as the mines already mentioned. No coal is shipped from this mine, it being used exclusively in the furnace. The workings of the coal mines are suspended much of the time.

The two shipping mines, the Eureka shaft and the Kyle slope, do not rely on any of the blast furnaces of the county for a market. The capacity of these mines is about 150 tons per day, but they could readily be raised to a capacity of 250 or 300 tons if the necessities of the coal trade required it. The coal in each mine is good, of the average thickness of the district; it mines in larger masses; it is of inviting appearance, and as a furnace fuel, of good quality, but as a shipping coal the demand for this seam is limited. It contains too large a per cent. of ash to make it a favorite for house fuel or for the generation of steam so long as the finer grade of the Wellston or Coalton bed can be had at the same price.

Along the line of the Ohio Southern Railroad, two and one-half miles west of Jackson, several mines have been opened in this coal for shipping purposes, but they have been at best but feebly operated. The coal rises above the valley, and is accessible by drift mining. Its average thickness is a little over three feet.

The composition of the Shaft coal in Kyle, Shotts and Co.'s mine is shown in the accompanying analysis, made for the Survey by Professor Lord. The samples were taken by Mr. C. N. Brown from the loaded cars at the mine.

Jackson Shaft Coal (Lord).

Moisture	8.57
Volatile combustible matter	32.70
Fixed carbon	55.43
Ash	3.30
Total	100.00
Sulphur	0.47

These figures represent the seam at its best and mark a coal of the highest grade. The only drawback consists in the high percentage of water, which is one of the characteristics of the coal.

The Coalton or Wellston Field.—Jackson Hill Coal.

The Wellston or Coalton coal was discovered in 1872 by the Hon. H. S. Bundy, of Wellston. He was drilling for the Jackson Shaft coal at the time, and was under the impression that it was this seam he had discovered, a view shared by all the practical men of the region. This coal is present in the hills surrounding the village of Jackson, but is quite thin, measuring from 20 to 30 inches. In its progress north and east, it gains in thickness till at Wellston, 7 miles north-east of Jackson, it rises to 4 feet. It proved, like the Jackson Shaft coal, to belong to the same family, being dry and open-burning, and adapted for furnace use as it comes from the miner's pick. So well assured were the practical furnace men of this region in regard to the quality and open-burning character of this coal, that the Milton Furnace and Coal Company erected their stone coal furnace at Wellston before any practical test of the coal was made.

The Wellston seam extends through the same townships as the Jackson Shaft coal, but covers a greatly larger area, though it is not always met of mineable thickness. The floor of the seam is compara-

tively level, though arches are occasionally encountered in mining which rise to 25 and 30 feet in height. The coal gradually loses in thickness in ascending these subterranean hills, but it bravely holds on and dips to its normal level without break or want in its continuity.

This seam is due in the hills surrounding the village of Jackson 150 feet above the Shaft coal. It is 2 to $2\frac{1}{2}$ feet in thickness, and is mined for local consumption only. As a house fuel it is greatly superior to the Shaft coal. At Coalton, 4 miles north of Jackson, its average thickness is three feet; at Wellston, 4 miles east of Coalton, it is 4 feet thick.

A branch of the Ohio Southern Railroad, known as the Horse Creek branch, extends from Jackson to Wellston, passing up Horse Creek to Coalton in a northerly course, thence changing to the east along Pigeon Creek. The Toledo, Cincinnati and St. Louis Railway intersects the Ohio Southern at Coalton, thence runs along side of the Ohio Southern to Glen Roy, two miles east of Coalton. At Glen Roy, the roads diverge, the T. C. & St. L. curving southward. They again converge a mile south of Wellston on the Portsmouth branch of the Cincinnati, Washington and Baltimore Railroad. A branch of the T. C. & St. L. extends from the Wellston to Buckeye Furnace and to the cannel coal mines on Coal Run, in Milton township.

The seat of the coal mining industry of Jackson county is located on the Horse Creek branch of the Ohio Southern Railroad, between Jackson and Wellston, and on the Toledo, Cincinnati and St. Louis road between Coalton and Wellston.

On the Horse Creek road, between Jackson and Coalton, there are five different branches or switches on which mines are opened on the Coalton coal, namely, the Price branch, the Springfield branch, and the Eagle branch, situate on the west side of the road, and the Chapman branch and Ada branch on the east side of the road. These branch roads extend up the ravines which open into Horse Creek, and range from 300 yards to one mile in length. The following are the names of the mines and names of operators of the same on the respective branches:

West Side.—Price Branch—3 Mines.

Name of Mine.	*Name of Operator.*
Newport Mine	Newport Coal Co.
Price Mine	Price Bros.
Carr Mine	Jas. S. Carr.

Springfield Branch—4 Mines.

Lively Mine	John C. Evans.
Warth Mine	Mohler & Kissinger.
Springfield Mine	Springfield Coal Co.
Forest Mine	———————
*Chapman's Mine	H. L. Chapman.

Eagle Branch—1 Mine.

Eagle Mine	Eagle Coal Co.

East Side.—Chapman Branch—1 Mine.

Chapman Mine	H. L. Chapman.

Ada Branch—6 Mines.

Ada Mine	Hall Coal Co.
Slope Mine	Mohler & Kissinger.
Wilson Slope	———————
Indiana Mine	Drew & Wasson.
McKitrick Slope	McKitrick Bros.
Hurd Shaft	Hurd Coal Co.

All the mines opened in the Price, Springfield, Eagle and Chapman branches are drift or level-free mines. On the Ada branch the Ada mine only is level-free. Of the other 5 mines 4 are slopes, and one, the Hurd, is a perpendicular shaft.

The coal is nowhere on this branch more than 30 feet below the surface.

The average thickness of the coal on these branches is about 33 inches; the thinnest coal being found, as a rule, to the south and west of the belt. As the coal loses in height it seems to gain in quality.

At Coalton, the point where the Ohio Southern and Toledo, Cincinnati and St. Louis railroads meet, nine different firms are mining coal, some of whom have 2 or 3 openings in operation. South and west of the village the coal is above drainage, but half a mile west, on Pigeon Creek, it plunges under the valley where the old Hamden road crosses the railroad. East of this point all the mines opened in the Coalton or Wellston coal in the county are reached by shaft mining.

The following are the names of mines and operators in the Coalton district:

*This mine is on the main branch.

Coalton Mines.

Wilson's Mine	John Hippel.
Hall's No. 1 and 2	John Hall.
Morgan & Jones, Nos. 1, 2 and 3	Morgan & Jones.
Kelley Mine	Kelley Coal Co.
Western	Western Coal Co.
Sterling	Sterling Coal Co.
Southern Ohio, 1 and 2	S. O. C. & I. Co.
Garfield Mine	Garfield Coal Co.
Cannel Bank	Adam Scott.

The Cannel mine, as its name indicates, is opened in cannel coal. The cannel appears here as a local deposit of only a few acres in extent. It is the Coalton seam, locally replaced by a formation of cannel. Sometimes the whole seam appears as cannel, but generally the lower part of the bed retains its bituminous character, about one-half being cannel and one-half ordinary Coalton coal. On the opposite side of Pigeon Creek and in the mines opened above and below the cannel bank, the cannel is absent.

A mile north-east, however, the cannel comes in again and spreads itself over an area of several square miles, but it is, so far as known, of very inferior quality, being in fact nothing more than bituminous shale. A foot of the lower part of the seam is, however, bituminous coal of good quality.

The average thickness of the Coalton mines is a little less than three feet; occasionally the seam swells to four feet, and sometimes it recedes considerably below three feet.

At Glen Roy, two miles east of Coalton, the point where the two railroads diverge, 3 mines are opened and another will be sunk during the summer. The mines now in operation are:

Standard	Standard Coal Co.
Emma	Emma Coal Co.
Acorn	Jones Coal Co.

These are all shafts, varying from 50 to 80 feet in depth. The height of seam in the Glen Roy mines varies from 3 to 3½ feet. The coal is well under cover in this field, and is nowhere cut out by ravines.

Two miles north of Glen Roy the seam runs into a bastard cannel or bituminous shale, and two or three miles south it seems to be replaced by the same material near the village of Berlin. A mile or so

south of Berlin, it recovers itself again, having been found of good mineable height in a hole bored on the lands of Samuel McShee on the Ironton branch of the T. C. & St. L. R'y. It is here 117 feet below the surface, and was reported to exceed 4 feet in height.

There are 10 mines in the Wellston district, viz.:

Name of Mine.	*Name of Operator.*
Wellston, No. 1	Wellston Coal & Iron Co.
Wellston, No. 2	Wellston Coal & Iron Co.
Milton	Milton Furnace & Coal Co.
Eliza	Eliza Furnace Co.
No. 3	Southern Ohio Coal & Iron Co.
Fluhart's	Theo. Fluhart & Co.
Meadow Run	Meadow Run Coal Co.
Comet	Cin. Consol. Coal Mining Co.
Center Valley	Drew & Wasson.
Murphin's	Murphin & Co.

The above are all shaft mines, varying from 50 to 100 feet in depth. The coal is of an average thickness of three feet nine inches, occasionally falling to three and one-half feet and rising to four and one-half feet. The most easterly mines contain the thickest coal.

The Wellston Coal and Iron Co., the Milton Furnace and Coal Co. and the Eliza Furnace Co. have blast furnaces along side of their mines, which receive their supply of coal from this seam. The Wellston Coal and Iron Co. have two blast furnaces, both located at their Number 1 shaft. These mines, in addition to furnishing coal for their respective furnaces, ship considerable coal over the Ohio Southern and the Cincinnati, Toledo and St. Louis Railroads. All the other mines of the district rely exclusively upon shipping.

All the coal of the Wellston or Coalton district, in which there are 41 mines in operation, is drawn from the same vein. The coal is remarkably uniform in character and thickness. As will be observed, in following the line of mines from Jackson to Wellston, the seam gradually gains in height, rising from 2½ at Jackson to 4 feet at Wellston. At the south-west end of the region the coal is noted for the small amount of ash it contains—frequently less than 2 per cent. of the whole. To the north and east, as the coal thickens, the amount of ash increases to 5 and 6 per cent.

The seam is a homogeneous mass, and is met under a firm cover of blue shale which forms an excellent roof, and is underlain with a soft,

fire-clay floor. West of Wellston the roof shale is replaced by a massive bed of sandstone over a considerable area; and at the Murphin mine the sandrock has cut down into the coal, forming a horseback. With the exception of this fault, which is merely local, no other mining trouble has yet been encountered in the region.

This coal, like the Jackson Shaft coal, belongs to the family of open-burning or furnace coals. It is, however, of a rather tender nature, and is not fitted to bear a heavy burden in the furnace. In the process of mining, fully two-fifths of the coal is converted into nut and slack. This large per cent. of nut and slack, however, is not all made by reason of the tender nature of the coal, part of it being the result of the unskillful manner in which the seam is mined. The operators of the region exercise no concern in regard to the practical skill of their miners, in employing them, as the nut coal, for which the miner is paid nothing, is of nearly equal value in market to the lump coal. It is to the miner's interest to make as much round or lump coal as possible, as he is paid for lump only, but unskillful workmen never succeed in turning out as large round coal as the trained miner, accustomed to underground life from early boyhood. Of late years the art of digging coal has degenerated in Ohio, more reliance being placed upon blasting-powder than formerly. Coal is often blasted out of the solid and shattered into small, in a reckless and shameless manner, without any cause save that of the carelessness of the miner.

The aggregate annual capacity of the mines of the county is 1,200,000 tons; the product of the mines for 1883 has been estimated at a little over 400,000 tons. During the summer months there is a great falling off in the trade.

This coal has been rapidly finding a market in competition with our best Ohio and Pennsylvania coals in all the great coalless regions, west and north. Last year it was successfully introduced on the lake (Erie) as a steam coal, 30,000 tons being used for this purpose; during the present year the lake trade will double that of 1883.

At several of the mines three grades of coal are made, viz., lump, nut and pea. The size of the screens is: for lump coal, 1½ inches space between screen bars; for nut coal, ½ inch between screen bars; the pea coal is made by screening the refuse or slack, which is raised into a revolving circular screen by a self-loading elevator and sifted of fine or dust coal, the fine coal falling back to the ground, whence it is hauled away as refuse.

As the coal seam is remarkably free from impurities of every kind, the nut and pea coal of this county has no superior and perhaps no equal in Ohio or adjoining States.

The composition of the Wellston coal is shown in the following analysis made for the Survey by Professor Lord. The sampling was done in all instances by Mr. C. N. Brown:

Analysis of Wellston or Coalton Coal (Lord).

1. Wellston Coal and Iron Co., shaft No. 2.
2. Southern Ohio Coal and Iron Co., Coalton.
3. H. L. Chapman's New Mine, Section 9, Lick township.

	1.	2.	3.
Moisture	8.57	7.46	8.89
Volatile combustible matter	36.40	36.40	34.03
Fixed carbon	51.39	54.97	52.60
Ash	3.64	1.17	4.48
Total	100.00	100.00	100.00
Sulphur	0.61	0.68	0.96

It will be seen that the high reputation of the Wellston coal is fully justified by the results of chemical analysis.

The Manner of Mining.

The mine shafts of the county are rectangular in shape; they are generally made 8x16 feet. None of the shafts exceed 100 feet in depth; the cost of sinking does not usually exceed twelve dollars per foot. The drift or clay material down to rock or shale is timbered with plank three to six inches thick, laid skin-tight. The underlying walls of rock or shale stand in place without support.

The horse-gin is generally used for hoisting the debris of the shaft; little water is encountered, and with three good workmen in the pit at once, in shifts of eight hours, an average of 3 feet in 24 hours can be excavated. Greater headway is made in slate than in sandrock, as the former blasts better, and the sides of the shaft are more easily dressed. After the coal is reached, subterranean work is suspended until the hoisting machinery is raised. The shaft frame is made of 10-inch timbers, 32 to 36 feet in height; it consists of 4 timbers, planted one at each corner of the shaft; the landing for delivery of the loaded cars is made

22 to 23 feet above the mouth of the pit; the pulley wheels are placed on top of the frame; the tipple is 27 to 35 feet from the landing; the hoisting engine is usually set on the side of the shaft opposite the tipple within 10 feet of the shaft mouth; sometimes it is located at the end of the shaft.

A great variety of hoisting engines is used. Double engines are preferred to single ones. Crane Brothers' hoist and safety cage is, perhaps, the best and safest. A single flue boiler suffices for the generation of steam to do the hoisting and pumping. All the pits have double hoisting compartments; a loaded car being raised on one side as an empty one is lowered on the other side. The hoisting compartments occupy 12 feet of breadth, leaving 4 feet, which is set apart for pumping water and frequently for an upcast ventilating compartment, the exhaust steam from the steam pump at the bottom of the shaft rarefying and giving motion to the upward current. The engine house, shaft and dump house are enclosed under the building. A hopper set of weigh scales is placed at the end of the screen, and the lump coal in passing over the coal is caught in the hopper and weighed before it is delivered into the railway flats.

None of the shaft mines, except the Corse slope of the Southern Ohio Coal and Iron Co., have costly or elaborate machinery or other arrangements for lifting and dumping coal. Ten thousand (10,000) dollars will fully equip a mine, including the cost of sinking, as mines are operated in Jackson county.

The weight of loads raised through the shaft is from 1,000 to 1,800 pounds. Three hundred tons per day, at the best regulated shaft mines, constitute the shipping capacity of lump coal.

The slope mine of the Southern Ohio Coal and Iron Co., which has very costly and elaborate arrangements for handling coal, has a capacity of 600 tons per day.

Two plans are followed in working the mine, one by driving double entries, and the other by driving single entries. Only those mines in which the height of coal reaches 4 feet, work by the double entry plan, and not all of them do so. The new mine of the Wellston Coal and Iron Co., the Corse mine of the S. O. C. & I. Co., Fluhart's mine, the Center Valley mine and part of the workings of the Milton Furnace mine, all in the Wellston district, work by double entries. The parallel entries, each 8 feet wide, have a pillar 3 to 4 yards in

width left between them, which is cut through every 40 yards or less for air. The rooms are driven 70 to 80 yards, and extend both north and south, meeting in the middle. They are made 8 yards wide, a pillar of 3 to 4 yards being left between them for the support of the superincumbent strata. Break-throughs are made between rooms at intervals of 25 to 30 yards.

In the Coalton district, instead of driving double entries, one wide entry is made, and the material which is shot out of the roof to make height for the hauling roads, is built up on one side of the track, leaving a hollow space next the pillar to serve as an air-course. By this plan a saving is had in entry driving, and the air is made to play along the entry face at all times. As a temporary expedient this plan does very well, but after a few months the loose building of shale begins to settle and the air to leak.

Where single entries are driven, doors are placed at the mouths of rooms and break-throughs made between runs as soon as they are turned, for the purpose of getting forward air. These doors are never air-tight at best; they are frequently left open by the carelessness of the miners themselves, and bad air is found at the working faces of the mine.

The system of working with double entries, if systematic perfection in ventilation be desired, is greatly to be preferred over single entry work; but the latter method is cheaper than the former, and economy in mining has too often the first claim upon the managers of mines, as against the health and comfort of the miners.

In the majority of the mines of Jackson county, the undermining or holing is made on the top of the coal. This part of the seam is tender and friable, and is more rapidly cut than the bottom part of the bed, which in many of the miners' working places is a hard, unyielding bone coal. The undermining is made four to five feet deep, and powder does the rest; powder, in fact, is too often used to do the undermining also; though always unwisely. Three shots are ordinarily required to a room of 8 yards in width—one center and two rib shots.

In the four-foot coal mines, mules enter the rooms and haul away the coal. Where the seam is less than four feet, pushers, consisting of active young men, are employed to push the loaded cars from the room faces to the hauling roads, on the entries. These hauling roads are made four-and-a-half to five feet in height above the rail, a foot or

so of the roof being blasted out for this purpose. The roof in the rooms is never ripped, no matter how low the coal may be. A mule takes 4 to 6 loaded cars with ease along a well-laid and properly graded track. ' One of these animals, four-and-a-half feet high, will haul 20 tons per day over roads a mile in length. A pusher will push 12 to 15 tons, the amount of coal moved depending on the distance from the working faces of the miners to the hauling roads of the mules.

The main roads of mines are laid with "T" iron, 8 and 12 pounds to the yard, the 8-pound rail being chiefly used in the yard coal mines and the 12-pound rail in the four-foot mines. Wooden rails are used in all the rooms; they are often made of scantling, 2x4 inches, laid flat ways and nailed down on cross-ties, 1x6 inches, made of oak plank.

The width of the track varies from 2 feet 8 inches to 3 feet 3 inches, according to the taste of managers.

The miners in the Coalton district are paid 5 cents per ton more for digging than in the Wellston district and at Jackson, the price in the latter districts being the same as that of the great iron region of the Hocking Valley. The prices ruling during the past two years at Wellston were 80 cents in winter and 70 cents in summer. An average of 22 cents per ton in addition to the price of digging is required for the payment of day men, that is, haulers, pushers, tracklayers, dumpers, weighmaster, etc., etc.

SECTION III.—MINES OF JACKSON COUNTY ABOVE THE HORIZON OF THE WELLSTON COAL.

By Edward Orton.

The Jackson and Wellston coal fields having been treated in a separate section, it would require but few lines to describe the remaining mines of the county, if only those were considered that contribute to the general market, but the policy already adopted will be continued here, and a brief review will be made of the apparent possibilities of the field, as well as of its actual and very feeble present development.

The seams which are found in the county have been already enumerated on page 994, and, in the account of Vinton county, all those that are of workable volume have been briefly characterized. The description of the Vinton county seams applies with but few changes to the seam of Jackson county.

The numerous blast furnaces of the county have brought it about that the seams of ore are much more widely worked and much better known than the coal seams. The former therefore dominate the sections, and the measurements are commonly made from them.

Two ore seams in particular constitute the chief guides for investigation as well as the chief bases for measurement, viz., the limestone ore carried by the Ferriferous limestone, and the Franklin or Big Red Block ore, which lies about 100 feet below it. The order of the coals is as follows:

(Above) 120–150 ft., Upper Freeport coal, No. 7.
65–90 ft., Lower Freeport coal, No. 6*a*.
35–70 ft., Middle Kittanning coal, No. 6.
10–20 ft., Lower Kittanning coal, No. 5.

Ferriferous Limestone Ore.

(Below) 0–15 ft., Clarion (Upper) coal.
30–50 ft., Brookville coal, No. 4.

Interval, 100–120 *feet.*

Franklin Block Ore.

(Above) 10–20 ft, Tionesta coal, No. 36.
(Below) 0–20 ft., Upper Mercer coal, No. 3*a*.
40–60 ft., Lower Mercer coal, No. 3.

Two or three measured sections are here inserted to illustrate the geology of their general districts.

There are a number of elements well shown in the immediate vicinity of Madison Furnace. The order is as follows:

Coal blossom and clay, Lower Freeport, No. 6*a*.	
Sandstone, soft, yellow, massive, Freeport	17 feet.
Coal, Middle Kittanning, 12 to 14 inches, No. 6	1 "
White clay and sandy shales with kidneys of ore	16 "
Coal, Lower Kittanning, No. 5, 12 to 32 inches	1 "
White clay, drab shales	22 "
Ferriferous limestone, with its ore.	
Coal, Clarion, 3 to 5 feet, below limestone.	
Hecla sandstone, massive and constant.	
(Furnace cut out of solid rock).	

At Keystone Furnace the following section was obtained:

Sandstone, 20 feet, seen.	
Coal blossom (Brush Creek, No. 3)	233 ft.
Interval, not seen.	

Ore bench, small	190 ft.
Red clay	10 ft.
White clay	10 ft.
Buff limestone (Dugway ore?)	160 ft.
Interval, not seen.	
Ore bench and buff limestone	140 ft.
Upper Freeport horizon.	
Sandstone, massive, Upper Freeport, 50 ft. thick	94 ft.
Coal, Lower Freeport, 6*a*	90 ft.
Interval, not seen.	
Coal, Middle Kittanning, No. 6.	
Clay and shale.	
Sandstone, massive, 25 feet thick	30 ft.
Coal, Lower Kittanning, No. 5 (2½ feet)	27 ft.
Clay and shale.	
Ferriferous limestone	0 ft.
Coal, Clarion.	
Sandstone, Hecla, out of which furnace is cut.	
Brookville coal, 2½ feet, 50 feet below limestone.	

The two lower seams of the list of coals above given are not known to have any economic value in Jackson county. The Lower Mercer coal is scarcely more than a mark, especially from the central portions of the county southward, and the Upper Mercer, though fairly persistent, seldom reaches a thickness of more than 16 inches.

The 3rd, 4th and 5th seams of the list, viz., the Tionesta, Brookville and Clarion seams are of great value here as in Vinton county. Of the seams above the Ferriferous limestone, the 2nd and 4th are those of which present account is mainly taken. The Lower Kittanning coal, however, often reaches mineable proportions, especially in the southern part of the county.

The Lower Freeport is also worked in a few farmers' banks.

The Upper Freeport Coal.

Not much more can be said as to the actual development of the Upper Freeport coal, but its possibilities seem greater. Lying high in the scale, it holds but small areas in the county, being found only in the hills of Bloomfield and Madison townships. It is here known by various local names, as for example, the Lucas coal and the Ferry coal. The latter is found in Section 23, Bloomfield, with a thickness of 5 feet 2 inches. It is not certain that this seam belongs to this horizon, but the probabilities are in favor of this reference.

As to the Lucas coal, Mr. Roy describes it as a homogeneous bed, varying from four to six feet in thickness, melting in burning and thus making a hollow fire. It is a bright coal, of excellent appearance, and certainly deserves more attention than it has yet received. This seam, as will be borne in mind, is everywhere found in local basins, some of which constitute very valuable coal fields of themselves. Such a basin, as yet undeveloped, is known to exist in Gallia county, in the vicinity of Waterloo, and the well-known Bayley's Run seam, of Athens county, occupies another basin. A considerable area of coal, as thick and good as the Ferry and the Lucas banks, would add largely to the value of this field. The region in which it is to be looked for is somewhat inaccessible, and has not as yet received even the ordinary development of a country coal field.

The Lower Freeport seam, which ranges from 60 to 90 feet above the Ferriferous limestone, does not, so far as known, exhibit promise of supporting mines.

The Middle Kittanning Coal.

The Middle Kittanning seam, No. 6, of Newberry, is known in Jackson county by its southern name, viz., the Sheridan coal.

It is also known as the Washington Furnace seam. It lies 35 to 60 feet above the Ferriferous limestone. It is almost everywhere present, but its thickness often falls below fairly mineable proportions. It has as little value in Jackson county as in any county of the State that is traversed by it. It generally consists here of two benches, separated by a foot of fire-clay. This mark is characteristic for this region, as was first pointed out by the late Dr. L. W. Baker, to whose investigations a large part of our knowledge of this field is due. The benches of the coal seem to represent the middle and upper benches of the Nelsonville and Carbondale seam, the lower bench having entirely disappeared. Generally, the upper bench is not marketable coal, and thus it often results that only the middle bench of the seam is taken out. The poor quality of the upper bench is altogether what would be expected from the character of the seam as traced through a half dozen counties. The middle bench has a thickness ranging between 2 and 3 feet, and it is, in almost all instances, of excellent quality.

Mr. Roy furnishes a section taken on the Keystone Furnace lands

in Bloomfield township, in which a thickness of 6 feet is assigned to this seam. The section is an excellent one, and if fairly representing any large area, would ensure an excellent coal field. It is given below:

M. K. coal	Shale	4 feet.	
	Upper bench	3 "	
	Fire-clay parting	1 "	
	Middle bench	3 "	
	(Lower bench of seam wanting.)		
Bottom clay		3 "	
Shale		8 "	
Kittanning sandstone		24 "	
L. K. coal	Upper bench	3 feet.	
	Clay parting	0 "	2 inches.
	Lower bench	1 "	
Bottom clay		1½ "	
Sandstone		8 "	
Fire-clay		3 "	
Limestone ore		1 "	
Ferriferous limestone		7 "	
Black slate		1½ "	
Upper Clarion coal	Upper bench	1½ feet.	
	Clay parting	0 "	4 "
	Middle bench	1 "	
	Parting	0 "	1 "
	Lower bench	0 "	10 "
Bottom clay		2 "	

No other section has been reported in which the Sheridan seam shows a thickness of 6 feet in this county, but just beyond the county line, in Sections 18 and 19, Huntington township, Gallia county, two banks are open, about one mile apart, that show nearly the same thickness as that given, but the structure is seen to be different.

These are known as the Deckard and Calhoun banks, respectively. The structure is as follows:

Sandstone roof.	
Clay	3 feet.
Coal	12 "
Clay	24 "
Coal	36 "

The Ferriferous limestone is exposed near Deckard's bank, and the interval from top of limestone to top of coal is 63 feet. The section is as follows:

Coal—Sheridan seam	6 feet.		
Clay and Shale	6 "		
Sandstone—Kittanning	28 "		
Coal—Newcastle seam—reported	3 "	7 inches.	
Clay and Shale	20 "		
Ferriferous limestone—top of seam.			

The Lower Kittanning or Newcastle coal is preferred to the upper seam in this neighborhood. Wherever the limestone is found in this immediate district, it serves as a guide to the Kittanning coals, the lower of which is 15–25 feet above it, and the upper, 55 to 65 feet above.

The valley of Little Raccoon deserves more attention than it has hitherto received. The facts given above would indicate that a coal field of at least moderate possibilities may be developed here.

The seam is due in but three townships of the county, viz., in Milton, Bloomfield and Madison. It is known to hold less than three feet of marketable coal throughout much of this territory, and sometimes it is but little more than a mark. This is especially true in the western part of Madison. It does not, therefore, seem probable that it can add much to the mineral wealth of the county, aside from the unusual development in the valley of the Little Raccoon Creek, already noticed.

The Lower Kittanning coal, No. 5, of the old scale, is locally known in these three last-named townships as the sandstone coal, deriving this designation from the fact that a massive sandrock almost everywhere covers it. A sandstone is also found below it in many instances, and now and then the coal appears as a streak in a sandstone ledge. This stratum extends from Jackson county to the Ohio Valley and beyond, making a conspicuous element in all sections, and being a prominent feature in the topography. In Jackson county it is locally a decided conglomerate. This phase is well seen on Buckeye Furnace lands.

The Lower Kittanning Coal.

The lower coal is of much more value in this district than its companion seam, and it holds this character to the river. An unusual fact in connection with the seam is shown in this district. It is locally split into two coals, each having a thickness of 2 feet or more, and is separated by sandstone or sandy shales that attain a maximum of 8 or 10 feet. This splitting of the seam can best be seen south of Jackson county, and will be described in the following chapter, but a few

examples may also be noticed in the vicinity of Keystone Furnace. In Section 19, Huntington township, on the Deckard farm, already referred to, the blossoms of the seam are found 20 and 29 feet above the limestone.

The present working of the seam is indicated below. In Section 11, Bloomfield, it is opened and shows a thickness of 4 to 4½ feet, at a distance of 26 feet above the limestone. In Section 18, Huntington, it is 42 to 48 inches thick, and 23 feet above the limestone. In Section 14, Bloomfield, it is reported 4 feet thick, and only 15 feet above the limestone. In Section 5, Madison, near the furnace, this seam is mined for local use. It is 32 inches thick, and 22 feet from the limestone. The seam generally consists of 2 benches, the upper one being much the thicker. At the last-named point, they are 24 and 8 inches, respectively. At other points the seam is found with a thickness of 12 to 15 inches or even less.

By these statements the general character and promise of this coal seam can be estimated. While nowhere likely to become a basis of large operations, there will doubtless be found basins that will repay mining and help out the production of the general field.

The Clarion Coal (*Upper*).

The limestone coal, which lies next below, is the steadiest seam of the series throughout the county, and is by far the largest single source of fuel after the Shaft coal and the Wellston seam. It has the same characteristics as in Vinton county, being in all respects as good a coal as is yielded by this horizon anywhere. It is found in Lick, Franklin Jefferson, Madison, Bloomfield and Milton townships.

Several attempts have been made to mine it for shipment, but it is found that it cannot be sold at the same price as the Wellston coal in the same markets, and it cannot be mined andhandled for less.

The last attempt to place it upon the market was made by the Southern Ohio Coal Company, who opened a mine at Downerdsville, on Rich Run, on the line of the T. C. & St. L. (narrow gauge) Railroad, in Milton township. The structure of the coal is shown in the appended figure:

The coal could not be sold, and the mine was necessarily abandoned after a brief period. There is a great deal of coal sold in the markets of the State to-day that is in no respect superior to the limestone coal

FIGURE CXXXVII.
SECTION OF LIMESTONE COAL AT RICH RUN MINE.

of Jackson county, but the trouble is that this must be sold by the side of and at about the same price as the Wellston coal, which is one of the most admirable fuels of the entire bituminous coal field.

In Section 7, Madison, this seam is worked for local use. It shows the structure indicated below :

Ferriferous limestone, making roof of coal, 6 feet.

Coal	18	inches.
Parting	8	"
Coal	17	"
Parting	2	"
Coal	11	"

A lower bench is also claimed for the seam at this point.

The Brookville Coal.

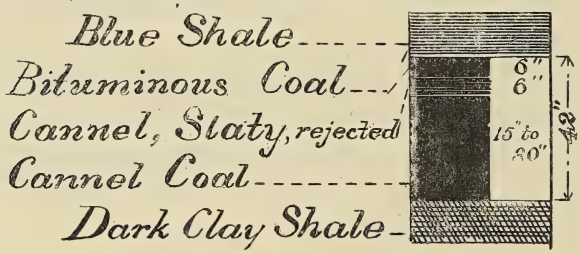
This seam is not worked at many points in Jackson county, but in the northern townships it is occasionally opened for local use. It is chiefly confined to Bloomfield and Milton. In both it is about 40 to 50 feet below the limestone. It does not exceed 4 feet in thickness in any sections that have been reported, and it falls to 2 feet in some. At Keystone Furnace it is 2½ feet thick. In Section 14, Bloomfield, it is 3 to 3½ feet thick. Considering its mineable character in Vinton county, it is a matter of surprise that the development of it in Jackson so scanty. Its place can be easily remembered, lying as it does close

under the Hecla sandstone, which is one of the main elements of the scale throughout this district. It is also known as being the first coal below the limestone coal.

The Cannel Coal of Milton Township.

The Tionesta seam, 3*b*, of the old scale, is found as a cannel of fair quality in Milton township, and probably in some other townships of the county. One shipping mine has been opened in it, viz., Mine No. 5 of the Southern Ohio Coal and Iron Company. It is located on the Coal Run branch of the T. C. & St. L. Railway, in Section 15, Milton township. The section is shown below:

FIGURE CLVI
STRUCTURE OF CANNEL COAL AT MINE No. 5, PATTERSON & CO. MILTON TWP.



The seam ranges between 15 and 30 inches in thickness, so far as worked. Its quality seems well approved in market.

It burns with a clear blaze, and does not leave an excessive amount of ash for a cannel coal. It is entirely free from flake and clinker. Its composition is shown below:

Cannel Coal of Milton Township (Lord)—Sampled by C. N. Brown.

Moisture	2.32
Volatile combustible matter	44.52
Fixed carbon	41.13
Ash	12.03
Total	100.00
Sulphur	0.84

The mine was opened in 1882, but the work has never been carried on extensively. Four entries are now driven into the coal, so that the mine is able to meet all demands. The structure and surroundings of the seam are as follows:

Sand rock.

Blue shale	15–20	inches.
Bituminous coal	6	"
Cannel—slaty—rejected	6	"
Cannel	15–30	"

Muddy shale.

The miner attacks the seam in the 6 inches of bituminous coal that caps it.

The position of the seam can be readily determined in most parts of the field by reference to the Big Red Block Ore, which is universally known. The cannel coal is the first seam above the ore, the interval between the two ranging from 10 to 30 feet. This brings it 65 to 75 feet below the Ferriferous limestone. In Vinton county, as will be remembered, a seam of large volume but of uncertain composition is referred to this horizon, viz., the Newland coal, of Elk township. The horizon is fairly steady throughout the district so far as some sort of an attempt at coal-making is concerned, but scarcely another opening on it is reported in Jackson county.

According to present knowledge, the Tionesta coal does not make an important addition to the mineral resources of Jackson county.

Summary.

It is thus seen that four seams of coal are mined in shipping banks in Jackson county. They are as follows: the Shaft seam, the Wellston coal, the Cannel coal, the Limestone coal.

The Shaft seam supports two shipping banks at Jackson in addition to the several furnace mines. There are also several small shipping mines along the railroad, west of Jackson.

The Wellston coal is the main-spring of the coal mining industry of the country. The development of this field has advanced with great rapidity. In 1878, not more than 10,000 tons of coal were shipped from Jackson county. During that year, two new lines of railway, built with the special object of reaching this coal, entered the field. The roads are the Ohio Southern (I. B. and W.), and the Toledo, Cincinnati and St. Louis R'y (Narrow Gauge.)

In 1880, the shipments reached nearly 300,000 tons, and in 1883, nearly 400,000 tons. During the past 6 years more than 40 mines

have been opened in this field, and it is at the present pretty well occupied.

A single mine has been opened in each of the remaining seams, but one is dormant and the other has not a very vigorous life. It is, however, certain that the limestone coal, by reason of its good volume, fair quality, and unbroken persistency, must at no distant day become the basis of a considerable mining industry in the county.

CHAPTER XVIII.

THE COAL SEAMS OF THE LOWER COAL MEASURES OF OHIO—Continued.

Mines of Scioto and Lawrence Counties, and of the Western Part of Gallia County.

By Edward Orton.

The general series of coals that we have already followed southward and westward from the Pennsylvania line can be traced with unmistakable distinctness from Jackson county into Scioto and Gallia, and through them into and across Lawrence county to the Ohio river. But, for several reasons, the coal seams are less conspicuous in this district than some of the other elements of the series. This is preeminently a furnace district, the charcoal iron manufacture of the State being centered here. Iron ores have therefore been sought for diligently, and the capabilities of the Lower Coal Measures to furnish a proper supply for the charcoal furnaces have been carefully investigated. The ore horizons are widely known and worked, but no similar motive has led to a like development of the coal seams.

In the second place, the coal seams are intrinsically less valuable in this district than they are in many of the counties already reported upon. In Scioto county, for example, the Jackson and Wellston coals are both due, but these two elements, which give such value to Jackson county, have no known economic importance here. In like manner the Nelsonville coal of the Hocking Valley has shrunk in Lawrence to a seam that sometimes holds but 28 inches of good coal, and that never exceeds 4½ feet.

The general section of the county has already been given on page 122, but a few additional statements will be made under this head.

The Ferriferous limestone is in full force and value in this district and is the stratum to which all other elements are referred when repre-

sented in vertical sections. In the map of Lawrence and Scioto counties, which accompanies this volume, the areas occupied by the limestone above drainage are shown, a task which would be impossible without the expenditure of great labor for any other elements of the scale except those directly connected with it. The limestone has been worked along its outcrops in practically continuous benchings throughout most of the furnace properties and through a great deal of other territory. The Ferriferous horizon indicates as well the horizon of the Kittanning coals, the lower of these seams being but 20 or 30 feet above the limestone, and the upper only 60 or 70 feet above, so that this boundary in Lawrence and Scioto and in Jackson and Vinton agrees very closely with the Kittanning boundary, as laid down upon the maps of the counties to the northward. Upon maps of the scale here employed, the two boundaries are, for much of the territory, practically identical.

Another ore horizon is very widely known and used, especially in determining the order of the lower portions of the series. It is the horizon of the main or upper block ore of the Ohio Valley. It is well named by Mr. Brown, the Franklin block ore, it having been the chief dependence of Franklin Furnace when in blast. It lies 110 to 120 feet below the Ferriferous, and 40 to 70 feet above the Lower Mercer limestone. There is pretty good reason to believe that this ore belongs to the Upper Mercer limestone, but whatever its exact northern continuation may be found to be, it is one of the steadiest and most easily recognized beds of the entire series in Southern Ohio. Mr. Brown made constant use of it in the western part of this field, and found it a guide almost as serviceable as the Ferriferous limestone ore. At many of the furnaces it is known as the big red block.

The little red block ore, which is carried by the Lower Mercer limestone, helps to support and confirm the sections. In determining the upper coals, the Cambridge limestone becomes of great value. It is constant in occurrence, and unmistakable in character, and leaves nothing to be desired as a ruling element in a geological section.

By the aid of these three well-known elements, all of the coal seams of the district can be so located that little trouble will be experienced in assigning any exposure to its proper place in the scale.

The coal seams that are *due* in this field are the 12 seams of the Lower Coal Measures (see page 127), but several of the series have not thus far been found of economic importance within the district. The

three lowest seams in particular have little or no value here. The Upper Mercer, the Tionesta, the Brookville and Clarion coals support at the best but feeble mines. The Kittanning and Freeport coals, 4 in number, furnish almost the entire coal supply of these counties, and seem likely to hold the same place for time to come.

The general section is as follows:

Cambridge limestone, generally in two beds.
Interval, containing Brush Creek coal, 130 feet.
Upper Freeport coal, Waterloo seam, Coal No. 7.
Interval, 40–50 feet.
Lower Freeport coal, Hatcher seam, Coal No. 6*a*.
Interval, 40–50 feet.
Middle Kittanning coal, Sheridan seam coal, No. 6.
Interval, 40 feet.
Lower Kittanning coal, Newcastle seam, coal No. 5.
Interval, 20–30 feet.
Ferriferous limestone.
Interval, 0–15 feet.
Clarion coal, in northern townships only, Coal No. 4*a*?
Interval, 50 feet.
100–140 ft. { Brookville coal, Coal No. 4.
Interval, 40 feet.
Tionesta coal, Coal No. 3*b*.
Interval, 10–20 feet. }
Franklin or Big Red block ore.
40–60 feet. { Interval, 15–40 feet.
Upper Mercer coal, Webster cannel, Coal No. 3*a*.
Interval, 20–30 feet. }
Little Red block ore.

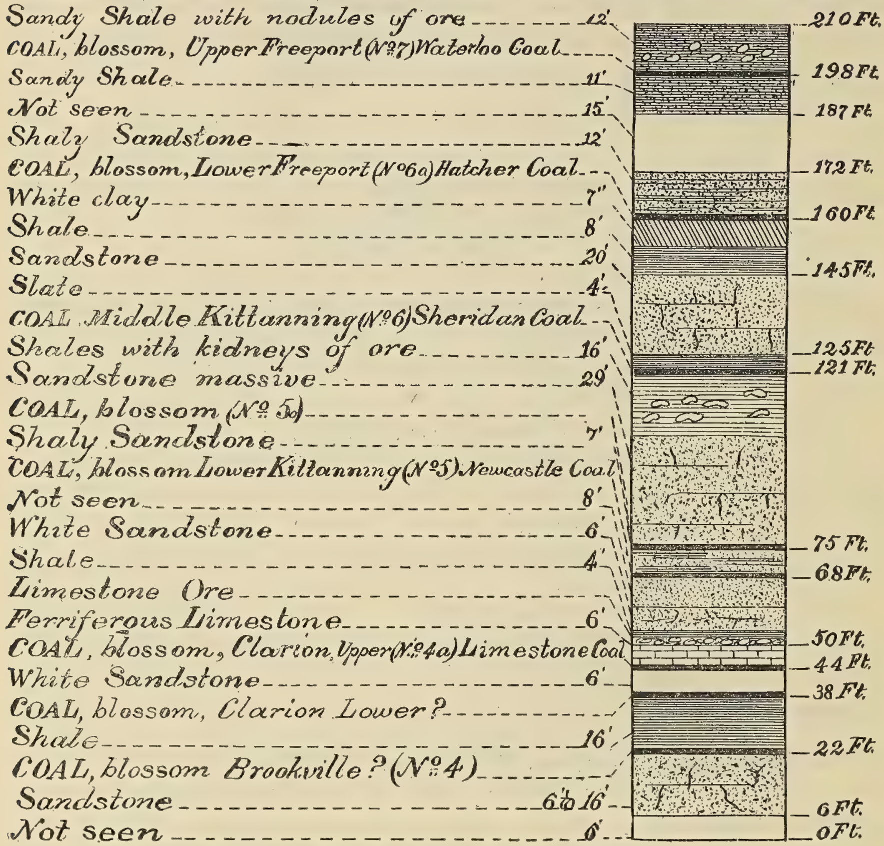
The places of the three lower seams are also indicated, counting from the last-named ore:

Interval, 0–15 feet.
Lower Mercer coal, No 3.
Interval, 90–120 feet.
Quakertown coal, Wellston seam, No. 2.
Interval, 50–100 feet.
Sharon coal, Jackson Shaft seam, No. 1.

A good representation of the elements likely to be found in any one section is shown in the accompanying figure. The section was carefully measured, and may be counted a type for the region to which it appears:

FIGURE CLIV

SECTION AT PANTHER HILL MT. VERNON FURNACE



VERTICAL SCALE 50 FT. TO ONE INCH

The seams below the Ferriferous limestone will first be considered.

The Upper Mercer (?) *Coal in Lawrence and Scioto.*

The coal seam to be described under this name cannot be certainly connected with the Upper Mercer seam of Vinton county and northward, but it seems probable that the present reference is correct. The doubt in the case extends to other elements as well. There seems to be but one coal seam with any claim to persistency between the Lower Mercer limestone and the Franklin block ore. The latter, as will be remembered, has been referred in the same uncertain way to the Upper Mercer limestone horizon. The difficulty in regard to the coal arises

from the considerable interval that separates it from the ore. By the table given above, it will be seen that this interval ranges between 15 and 40 feet. The first figure would create no difficulty, and the second, perhaps, need not, when the gradations are established between these extremes.

At all events, a persistent but not very valuable seam holds this place in the scale. It is close to and may replace the sandblock ore. It generally consists of two benches separated by a band of shale, and is hence sometimes known as the slate vein.

In the river hills, the place of the seam is about 30 feet below the Franklin or main block ore. It is mined in Section 8, Hamilton township, Lawrence county, and also on lot 16, Greene township, Scioto county. The former is known as the Collins coal, the latter, which is a cannel, as the Fulsom coal. The Collins coal consists of two benches, separated by 6 or 8 inches of clay or shale. The entire thickness is sometimes 4 feet. It is also seen on lot 44, French Grant, 28 feet below the main block ore. On Sections 2, 3, 8, 20, 21, 26, 31, 34, Elizabeth township, the presence of the coal has been marked. Throughout this region it ranges from 12 to 20 inches in thickness. Its quality seems good. On section 14 and 26, Decatur, it is also present.

It is mined and shipped to a small extent at Pioneer Station, Scioto county, the seam here being known as the Webster cannel. It is 16 to 20 inches thick. It is only locally a cannel, the same seam being entirely bituminous at other openings in the neighborhood. Cook's cannel mine, half way between Bloom Furnace and Pioneer Station, occasionally ships a little coal by rail. There is here a fine exhibition of stigmaria in the bottom slate. The Webster Brick Works mine this seam south of the village, the coal being 36 inches thick, and being known as splint coal.

It is not necessary to name other exposures of this horizon. The best that have been found have been already reported. This is Coal No. 3 of the Kentucky series.

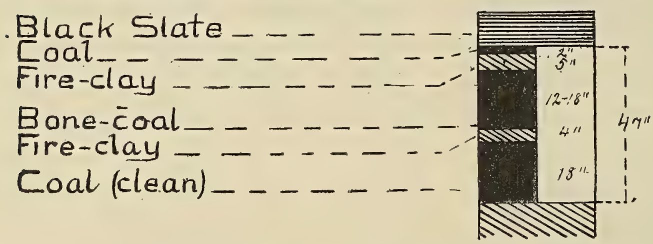
The Tionesta Coal, No. 3b, No. 4 of Kentucky.

The place of this coal is well-marked by the Franklin or main block ore, which lies just below it, the interval being 5 to 20 feet. This places it at about 80 to 100 feet below this Ferriferous limestone. A peculiarity of the horizon is the splitting of the seam into a number

of thin streaks of coal distributed through 10 to 20 feet of clay and shale. Its maximum thickness, so far as observed, is 36 inches, the seam giving this measure in Section 14, Vernon township. Near Pine Grove Furnace also, a good thickness was observed, but it often runs down to 6 or 8 inches. The coal is mined in such few instances, and in such a small and irregular way, that no judgment can be given as to its quality. This appears to be the "slate vein" of Washington Furnace, the designation being given on account of the black slate roof of the coal. Its structure is shown in the accompanying diagram:

FIGURE CXL.

SECTION OF "SLATE" COAL AT WASHINGTON FURNACE



There is no promise given by this seam in the district of large mines, but it will long yield small local supplies to farmers and furnace hands who can obtain a winter's stock by benching or stripping in favorable locations.

In Kentucky, this seam becomes in certain areas a cannel of good quality. The Hunnewell and Chinn's Creek cannels are referred to this horizon.

The Brookville Coal, No. 4, of Newberry, No. 5, of Kentucky.

A somewhat more important seam in this district than either of those already named is the Brookville coal. It has been described under two numbers in previous reports, viz., as No. 3c and as No. 4. There is but little doubt that it comes in upon the Putnam Hill limestone horizon, and that, therefore, the latter number belongs to it. It is known as the Conway coal in the neighborhood of Ironton, where it has been mined in a small way in years past. Its place is 50–70 feet below the Ferriferous limestone. It does not show as great a thickness in this district as in Vinton county, so far as it has been observed, and

nothing that is known of it warrants the expectation that it can at any time support important mines.

On the south side of the river, the seam does not possess much value according to Professor Crandall's reports.

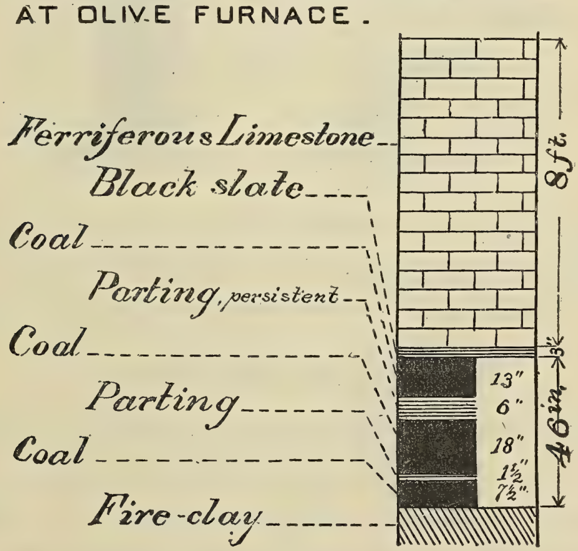
The Clarion Coal (Upper), No. 4a.

This seam, which is so well-known and so highly esteemed in Jackson and Vinton counties, under the name of the *Limestone Coal*, enters Scioto and Lawrence counties from the northward in good volume and good condition, but it disappears abruptly from the series near the middle of Decatur township. An east and west line drawn through Mt. Vernon Furnace will leave all the coal of this seam to the northward. It disappears not only suddenly, but completely. At least but few traces or hints of it are found south of the line named. In Kentucky, the horizon is passed without notice, so far as coal is concerned.

The coal is found in portions of Washington and Decatur townships, of Lawrence county, and of Bloom and Vernon townships, of Scioto, and Greenfield township, Gallia county, under the conditions already described for the northern counties. The volume of the seam is good, but it carries at least two partings, one of them being a per-

FIGURE CLV

STRUCTURE OF LIMESTONE COAL AT OLIVE FURNACE.



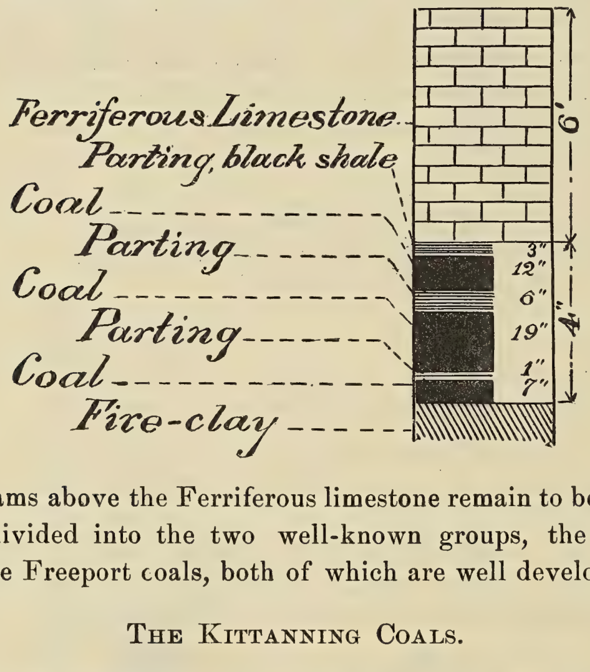
sistent band of shale or clay, 6 inches in thickness. This structure would require great care and necessitate unusual labor in preparing the coal for the general market. So far as observed, the structure is fairly regular. At Olive Furnace, in Section 3, Washington, it shows the structure represented in the accompanying figure.

Close upon the line of its final disappearance, on the land of Henry Warnecke, Section 15, Decatur township, the same structure is repeated, the measurements being almost identical.

Considerable areas are occupied by the seam in the districts named, and the same statements as to mining possibilities are warranted here that were made in regard to this coal in Jackson and Vinton:

FIGURE CXLV

STRUCTURE OF LIMESTONE COAL ON HENRY WARNECKE'S LAND SECTION 15 DECATUR TWP.



The seams above the Ferriferous limestone remain to be considered. They are divided into the two well-known groups, the Kittanning coals and the Freeport coals, both of which are well developed here.

The Kittanning Coals.

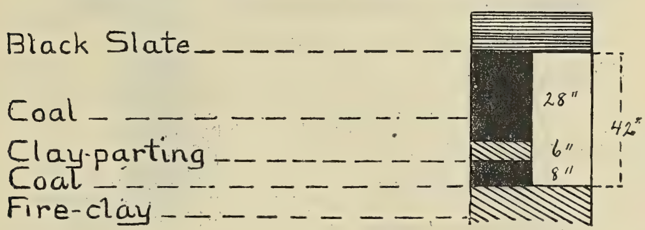
The Lower Kittanning Coal, Coal No. 5—No. 6, Kentucky.

This persistent but seldom valuable seam is found in good thickness and of fair quality in much of the territory under consideration. Its position is well known and easily marked, inasmuch as it lies within 15 to 25 feet of the great limestone ore horizon.

At Washington Furnace many small banks have been worked in the seam. It shows here the structure represented in the following figure, which represents its normal composition of this region :

FIGURE CXXXVIII

SECTION OF LOWER KITTANNING COAL (NO. 5), AT WASHINGTON FURNACE



Its quality is fair, as has been before stated. It is rather high in sulphur and also in ash, but it burns readily and lasts well in the fire. It is valued for steam generation wherever it is used.

At Lawrence Furnace, Section 4, Elizabeth township, the seam has in like manner been long mined in a small way. Throughout this township and also to the southward and eastward, a massive sandstone separates the Kittanning coals, often coming down directly upon the lower seam. This is shown in the following figures:

FIGURE CXLIII

SECTION AT LAWRENCE FURNACE

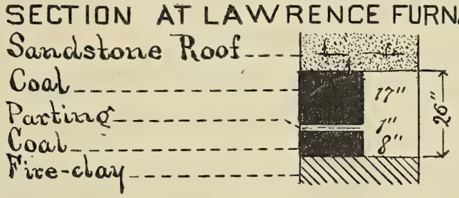
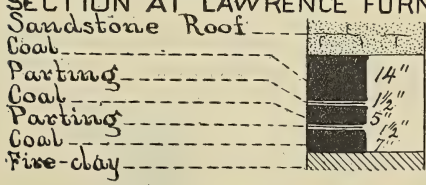


FIGURE CXLIV

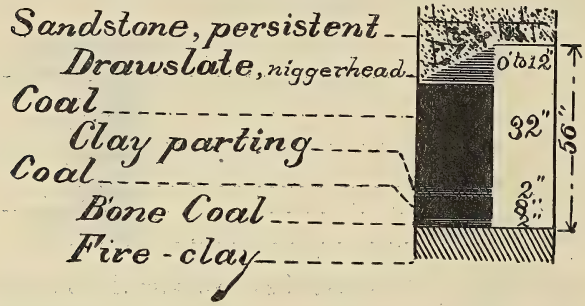
SECTION AT LAWRENCE FURNACE



It will be seen that the upper bench is reduced from the measure previously shown by the descent of the sandstone, and that the thickness of the coal is thus brought below fairly mineable proportions.

In Section 20, Elizabeth township, on Etna Furnace lands, the seam is shown again in normal structure:

FIGURE CXLVI
STRUCTURE OF LOWER KITTANNING COAL (No. 5) AT ETNA FURNACE.

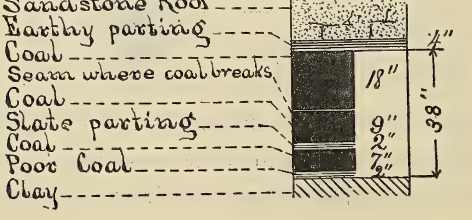


In the workings, however, the roof shales, known as "the draw-slate," are often cut away, to the detriment of the seam.

The New Castle Field.

The largest and the only important mines in the seam in these counties are found at New Castle, on the railroad to Pine Grove Furnace, and at Vesuvius Station, on the Iron Railroad. By the New Castle mines the supply of Hanging Rock is produced, and they also furnish a large amount of coal for river steamboats. The Vesuvius Station or Tunnel mines furnish almost the entire supply of Ironton, both for manufacturing and domestic uses. Three rolling mills, in particular, rely entirely on the Tunnel mines, and, in fact, it is upon these mines that all the manufacturing interests of Ironton have been built up. For all uses, the coal is fairly well approved. The seam holds quite uniformly and steadily a thickness of 42 inches. It lies 20–24 feet above the limestone. Its structure is shown below:

FIGURE CXLVII
SECTION AT NEWCASTLE. COAL No. 5



An analysis made for the Survey shows the following composition, which probably represents the average product of the mines:

New Castle Coal, Tunnel Mines (Lord).

Moisture	5.19
Volatile combustible matter	41.86
Fixed carbon	47.69
Ash	5.26
Total	100.00
Sulphur	1.40

Experiments have recently been made in coking the New Castle coal. A quantity was sent from Ironton to Pittsburgh for this purpose. The coal was crushed and washed, and the resulting coke presents an excellent appearance.

The daily production of the two centers already named will range between 300 and 500 tons. A large acreage has therefore been exhausted in the 20 years during which mining has been carried on here, but the field shows no signs of giving out. A considerable territory may be counted on as affording a safe basis for shipping mines. Scores of country banks are opened throughout the district that show the same conditions that are found at New Castle and Vesuvius Station. In the vicinity of Ironton, in particular, a large amount of coal has been taken to meet the local demand, and the mines have already occupied or exhausted the whole range of front hills.

The furthest point that the seam reaches on the river front in going westward is a hill in Section 8, Hamilton township. Only the mark of the seam is shown here.

All things considered, the New Castle field deserves to be counted one of the most valuable basins of Lower Kittanning coal in the State. Perhaps the Leetonia field is the only one that outranks it in value.

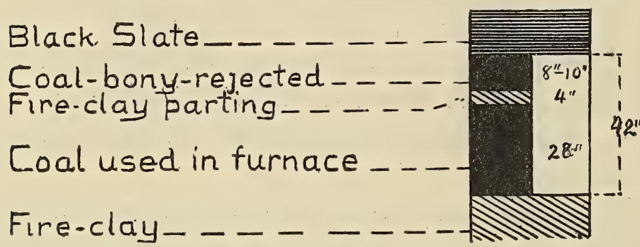
The Middle Kittanning Coal, Coal No. 6—Coal No. 7, Kentucky.

This seam is not found in Scioto county. In Lawrence and Gallia it is commonly known as the Sheridan coal. Though lacking the splendid development that it attains in the Hocking Valley, it is still a steady and excellent seam. It maintains its character as *reliable.* Though falling to a measure that is not at present consistent with large operations for most of the field, it still affords the safest supply of most

of the regions where it is due, and will doubtless be hereafter followed under its heaviest cover. Its quality is always fair and often excellent. A few sections will be furnished, illustrative of the character of the seam throughout the district.

At Washington Furnace it has the structure represented below:

FIGURE CXXXIV
SECTION OF MIDDLE KITTANNING COAL (NO.6), AT WASHINGTON FURNACE MINES



It has been worked at this point in the large way for a number of years, the coal having been found to be certainly the only seam that could be used to replace charcoal in iron manufacture at this point, the timber for the latter having been exhausted. The earlier trials with this seam were unsuccessful. Attempts were made to coke the coal, but the open-burning nature of the seam forbade good results in this direction, and the most that could be done was to char the coal and expel part of its sulphur. Success was gained at last by largely increasing the flux of the charge, when it was found that failure had not at any time been due to the coal. Only the middle bench, 28 inches in thickness, is taken, and consequently there is a rapid reduction in available acreage of the seam. The coal thoroughly approved itself as one of the few that can be used raw in the smelting of iron.

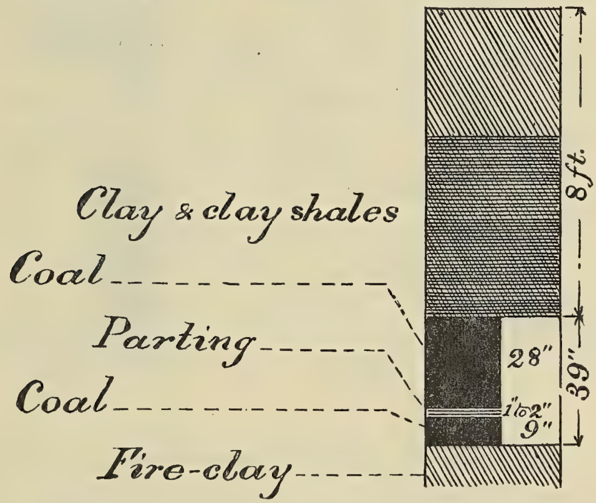
The next section of the seam that is represented comes from Decatur township. On the lands of Mt. Vernon furnace, Section 22, it shows the structure indicated below.

The lower bench, which is wanting in the Washington section, reappears, and clay shales take the place of the bone coal there shown. The middle bench is the heart of the seam in all of the fields that it occupies. This bench holds nearly the same thickness here as in Perry county.

A few notes will be given at this point as to certain coal seams of Gallia county. The observations are miscellaneous, and are counted

useful only as giving to local explorers clues which they can safely follow.

FIGURE CXLI
STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) ON LANDS OF MT. VERNON FURNACE.



GALLIA COUNTY.

The Sheridan seam appears to extend continuously from Washington township to the eastward, as far as the Valley of Raccoon Creek, in Perry township, where it falls finally below drainage. At least the seam is shown in this valley in good condition and in good proportions. Its structure is indicated below:

This section is quite familiar and reassuring. It would be a normal section in the Hocking Valley. Not only do the three regular benches again apear, but the supplementary seam of the Hocking Valley is also represented. The 3 inches of coal and the black slate of the roof show an approach to the conditions under which the *great* phase of the seam was built up.

The coal has been worked for many years at Evans's mill for steam production and for local supply. It stands in high estimation, and certainly gives promise of a field of great value for future mining enterprises.

FIGURE CXLVIII
STRUCTURE OF MIDDLE KITTANNING COAL (No. 6) AT EVANS' MILL.

A long and excellent section illustrative of the geology of the region was measured here with great care by Mr. Brown and is represented below. It may be relied upon as a safe guide in explorations that will follow.

The character of this seam in Huntington township has been already touched upon in the discussion of the coals of Little Raccoon valley (see page 1029). The Deckard and Calhoun coals, as reported, seem to have unusual promise.

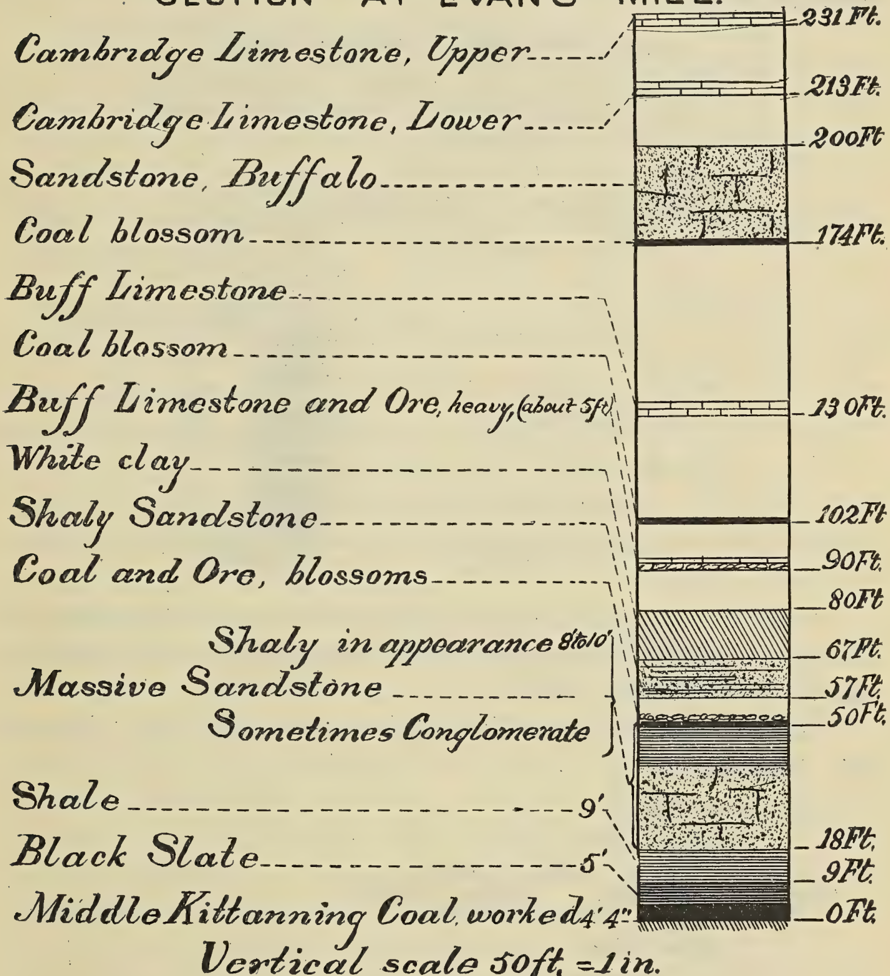
In Raccoon township there is but little development of coal seams and the sections presented are somewhat ambiguous and uncertain. At Centerville the following series is found:

Heavy sandstone.	
Coal seam, known as Thomas coal	125 feet
Coal blossom, often seen	115 "
Buff limestone	100 "
Coal, 18 to 24 inches	70- 80 "
Coal	31 "
Hard stratum, found at depth of 70 feet.	

The translation of the terms seems to be as follows:

Sandstone—Upper Freeport sandstone.
Thomas coal—Lower Freeport coal.
Buff limestone—Lower Freeport limestone.
Coal, 18-24 inches—Middle Kittanning seam.
Coal, lowest—Lower Kittanning seam.
Ferriferous limestone.

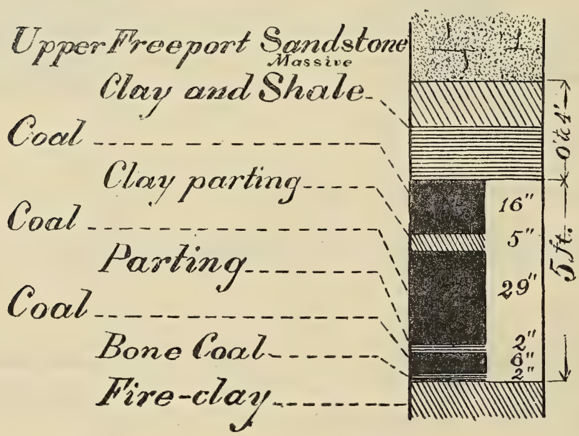
FIGURE CXLIX
SECTION AT EVANS' MILL.



In Section 6, Perry township, near Wales, two thin seams of coal are mined for neighborhood use, the lower one being 22 inches thick and a solid bed; the other is 8 to 10 feet above it. These seem to

represent the Centerville coal (Thomas seam), the same heavy ledge of sandstone covering the upper seam. The sandstone can be followed up the Grassy Fork of Symmes Creek, where it is again found covering a coal seam. The latter is well shown on David Williams's land, Section 2, Madison township. It here consists of two benches, the upper one, 14 inches thick, and the lower, 21 inches, separated by an 8-inch clay parting. This seems to be the same coal found at Gallia Furnace, at 88 feet above the Ferriferous limestone. At Shelton's bank the seam shows the structure represented below:

FIGURE CXLVII.
STRUCTURE OF LOWER FREEPORT? COAL (No. 6a) AT SHELTON'S BANK NEAR GALLIA FURNACE



There is a question in regard to the Shelton coal, as is indicated in the figure. It has the partings of the Middle Kittanning seam, and may possibly be on this horizon.

On J. Calaway's land, in Section 12, Greenfield, the following series is shown:

Coal, Upper Freeport.
Interval, 54 feet.
Coal, Lower Freeport. { Coal, 10 inches. / Parting, 2 inches. / Coal, 26 inches. }
Interval, 66 feet.
Coal, Middle Kittanning.

About the identification of the lower coal there is no question, as the seam was traced directly into the Evans's Mill coal, already described.

In Section 7, Walnut township, on the farm of J. S. Eakins, the Middle Kittanning seam lies in the bed of Symmes Creek. The Lower Freeport coal also appears in the same section. The Cambridge limestone is here found, 242 feet above it, as at Evans's mill. This has now become the normal measure. The coal is 38 inches thick, and very promising in appearance.

At Armstrong's bridge, in Section 12, Walnut, the coal is again found, 30 feet above Symmes Creek. The Upper Freeport coal is about 120 feet above it in this vicinity.

These sections and measurements, taken somewhat at random, will lend some light to future explorers, but this whole district needs that more time and labor be spent upon it before a full account of its resources can be given. There is no peculiar complexity in its stratification, but the openings of its coal seams are infrequent, and the intervals between its several elements are somewhat changed from those found on the margins of the field.

Returning to Lawrence county, a few additional statements as to the Middle Kittanning coal, No. 6, are needed to complete the cursory account here undertaken. The seam is generally found in its proper place in the section wherever its horizon is exposed, but it has suffered a good deal from the erosion of the Lower Freeport sandstone, which is steady throughout the county, and very massive. It often comes close down upon the coal, cutting away its roof shales and deteriorating its quality. Not infrequently it intrudes into the coal, reducing it below mineable proportions.

In the river hills, near Ironton, this last condition prevails. The coal is seldom found thick enough here to warrant mining, and the lower seam, as has been already stated, is the universal reliance. Above Ironton, however, the seam shows a better condition, and the only extensive mines of the county in this coal have been opened here. They are located at Sheridan, about 6 miles above Ironton. The coal lies low in the hills, and is not found again above the river after leaving this immediate neighborhood. The Sheridan mines were opened about 1863, and for a number of years maintained a large output. They were equipped for delivering coal upon the river, at good advantage. The quality of the coal has always been approved. In thickness, the seam does not often fall below 3 feet in the areas that have been worked, and it sometimes rises to 4 feet. The average of the Sheridan mines will

not much exceed the former figure. The sandstone comes down close upon the coal, and the hill under which it is mined is very heavy. The floor is somewhat irregular, but the seam has its usual persistency and steadiness. A considerable acreage has been worked out. Mining has been suspended here for several years.

There is no reason to doubt that all of this seam in the county that is 3 feet and over in thickness will be called for in time to come, but it is quite possible that it cannot be brought into successful competition with the thicker and more easily mined seams of adjoining fields at the present time.

The fact that the Sheridan mine is not now producing coal will account for the analysis of the seam being wanting at this point.

The Freeport Coals.

Under this head the two remaining seams of the Lower Measures of Lawrence and Gallia counties will be briefly noted. One of these seams has already been brought into account, incidentally, as it is found in some of the western townships of Gallia county (see page 1028).

The Lower Freeport Coal, Coal No. 6a.

This seam is known in Lawrence county as the Hatcher coal. It lies 40 to 60 feet above the Middle Kittanning coal. It is fairly steady through a considerable territory, particularly to the east and north of Ironton. In thickness, at its best, it ranges between 3 and 4 feet. Its quality is fair. Whether it can support shipping mines successfully, under present conditions, has not been determined by actual experiment, but the probabilities are not favorable to such a result. This seam has not, at least, been turned to such account at any point on the western side of the coal field. It furnishes a fair amount of coal for neighborhood use, and will long serve this not unimportant end. It promises more in Lawrence county than in any of the counties of the western margin of the field.

The Upper Freeport Coal.

The Waterloo Field.

A basin of this coal that promises to take rank with the best deposits of Upper Freeport age in the State is to be found in parts of Walnut, Symmes and Aid townships of Gallia and Lawrence counties.

It is perhaps the most valuable body of this coal in the State that has not yet been attacked. The name by which it is most commonly known is the Waterloo coal, the little village of this name on the Lawrence county line marking the best known center of the field. The basin extends in a southerly direction along the valley of Symmes Creek, from about Waterloo for 8 to 10 miles, but we can well believe that some interruptions would be developed by working within these limits. The opportunities to estimate the extent of the field in an east and west direction are comparatively few, being confined to the transverse valleys that are cut deep enough to expose the seam, but a breadth of 2 to 3 miles, it seems safe to infer from such facts as are met with. One fact of special importance is to be noted, viz., that the coal descends to its final cover on the east side of Symmes Creek in its best condition. A valuable extension of the seam below drainage is attested by this state of things. The area occupied by the coal, as it is now known, is roughly indicated on map No. 8.

It is to be regretted that all of the statements made in regard to the Waterloo field must be somewhat vague and general. This results from the fact that the field has not yet been proved in any thorough or systematic may. Our knowledge of it, which is very little extended beyond that of former reports, is limited to such natural exposures as can be found in banks of creeks, in roadways, and on hill-sides, aided and re-enforced by a half-dozen farmers' banks, together with one or two mines in which 2 or 3 acres, more or less, have been worked out.

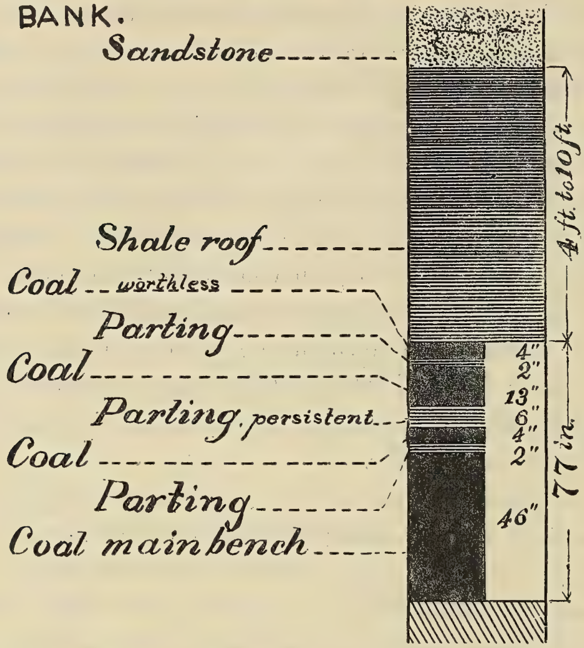
The general section that includes this coal has already been given (see pages 120–121). It lies 120 to 130 feet below the Cambridge limestone. The errors of statement in the earlier references to this seam, and especially my own errors in regard to it, in Volume III, have been noticed and corrected on an earlier page (see page 120).

Coming from the northward, the seam is first found in good development in the south-western sections of Walnut township. It has been mined by stripping for many years in the vicinity of Flag Spring. It shows here a thickness of five feet, and the quality of the coal is excellent.

Passing southwards one mile we reach the well-known mines of Jacob Webster, the largest workings in the Waterloo field. The structure of the coal at this point is indicated in the accompanying diagram:

FIGURE CL.

STRUCTURE OF UPPER FREEPORT COAL AT JACOB WEBSTER'S VALLEY BANK.



The seam consists essentially of two benches—a lower one, measuring 4 feet, in which almost its entire value lies, and an upper bench that here exceeds 1 foot. A persistent clay parting, 6 inches in thickness, separates the two benches. Under the main parting a thin band of coal is found, separated from the main body by a thin layer of shale. This middle band could not be gained in mining under the present system, even if its quality warranted, as the expense of splitting it out would exceed its value. The roof coal or upper bench is generally coarse and worthless.

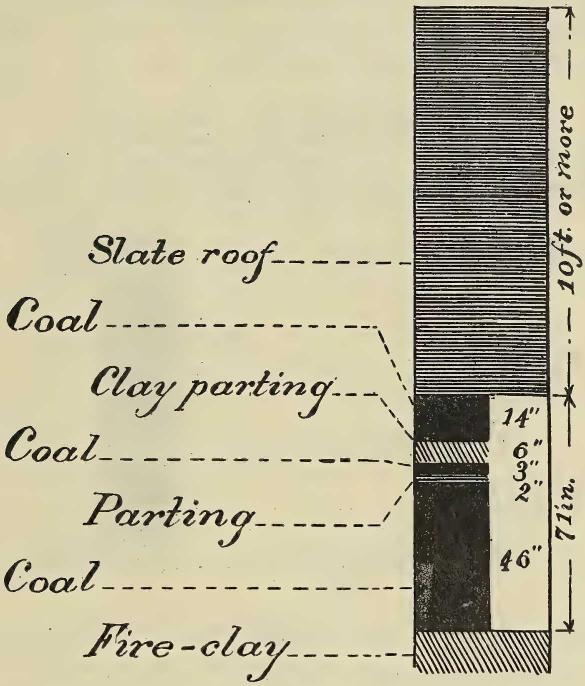
A heavy mass of slate overlies the coal, and it may reasonably be expected to form a good roof in regularly worked mines. In these country banks it proves somewhat troublesome and dangerous by falling.

A half-mile beyond Webster's, the fine showing of the seam on John Strait's farm is found. The coal has been worked here to a small extent, and it nowhere appears to better advantage.

On the farm of Thomas Cooper, a mile southward of Webster's, another bank is opened in the seam. Its structure at this point is indicated below:

FIGURE CLI

STRUCTURE OF UPPER FREEPORT COAL ON THOMAS COOPER'S LAND, WATERLOO.



The structure is seen to agree closely with the structure of the seam at Webster's bank, and also at Strait's, and we are thus warranted in believing that a continuous body of coal of this character occupies the entire interval. The maintenance of the heavy deposit of roof shales is also reassuring, inasmuch as it shows the thorough protection of the seam from early erosion.

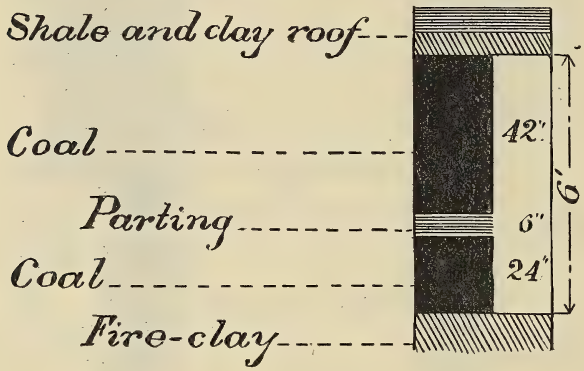
One mile further west, but still on the lands of Thomas Cooper, a second opening is found, agreeing essentially with the facts already stated.

The seam can also be followed to the northwest of Waterloo. On the line between Sections 14 and 23, Symmes township, on the land of George Pearce, it is found with a thickness of 37 inches. It appears probable that the reduction in volume is rapid in this direction. The Sheridan coal (Middle Kittanning) appears in the same farm and at no great distance, the Ferriferous limestone also comes into the section.

Southward from Waterloo the coal is found in all the tributaries of Symmes Creek that expose its horizon for 6 or 8 miles. The coal is

opened on John's Creek, on Aarons' Creek, and on Elkins's Creek. In the last-named valley are found the well-known openings of the Oak Ridge Furnace, Section 22, Aid township. The coal has been worked here in a small way for many years. The structure of the seam is shown in the following figure:

FIGURE CLII
STRUCTURE OF UPPER FREEPORT COAL (WATERLOO SEAM) AT OAK RIDGE F'CE.

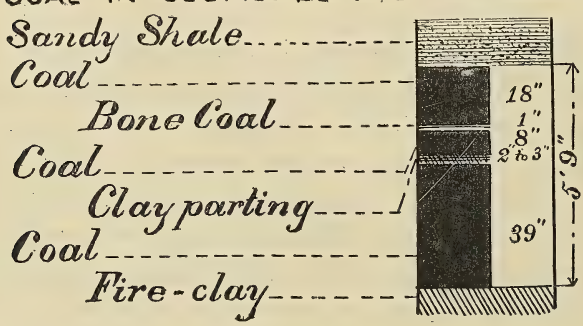


The volume, as will be seen, is fully equal to that of the Waterloo coal, but the benches are quite differently proportioned. The quality of the coal is inferior, so far as present developments enable us to judge. The seam is so interrupted by slate and clay banks that it can scarcely be made a basis for profitable mining.

One other section, illustrative of this field, is added.

In Section 28, Aid township, 2 miles to the southward of Oak

FIGURE CLIII
STRUCTURE OF UPPER FREEPORT COAL IN SECTION 28 AID TOWNSHIP.



Ridge Furnace, and in the Valley of Sharp's Creek, another tributary of Symmes Creek, the coal is again found. It has a thickness of 69 inches, all told, and its structure is shown above:

The seam is here regaining the structure and character of the Waterloo coal. The openings indicate good promise of a mining field.

Two and one-half miles east of this point, and in the main valley of Symmes Creek, on the east side, in Section 25, Aid township, there is found the last exposure of the Waterloo coal in this direction. The seam is mined here by the Russel Brothers. Its structure is as follows:

Russell coal.	Coal	10–12	inches.
	Clay parting	1	"
	Coal	3–4	"
	Clay parting	1–2	"
	Coal, bottom bench	39	"

All of the coal of the seam is mined, and no discrimination is made as to quality. The coal is held in good repute for blacksmith use, and is the exclusive dependence of the shops for 6 or 8 miles around. There is very little visible sulphur in it. It mines in large blocks, without the use of powder, but it is rather tender, and would not, perhaps, bear railroad transportation well. It is sold at the bank's mouth for 4½ cents per bushel. Royalty is paid at the rate of 25 cents per ton on lump coal.

This bank, it will be remembered, is on the east side of Symmes Creek, and the seam here dips down, never to rise again. The fact that volume and quality are so good in this last appearance is one of great significance. It warrants the belief in a valuable body of this coal below drainage.

The composition of the Waterloo coal cannot be given as fully as is to be desired. The banks are open only at certain seasons of the year, and at the time that samples were sought for, a number of the mines were obstructed with water, and could not be entered, but the three following analyses will do something toward showing the real character of the coal. The first samples were obtained from the stripping bank of Charles Neal, Section 19, Walnut township, near Flag Spring, on the northern boundary of the basin. The samples represented only the bottom bench. The second set was obtained from the entries of Thomas Cooper's bank, in Section 30, Walnut, and to this set the character of outcrop coal attaches in some degree. Only the lowermost

4 feet of the seam are represented here. The third samples come from the Russell Brothers' mine, already referred to, and represent the southernmost extension of the basin that is now worked. All of the seam is represented in this analysis, and the samples are the only ones that do full justice to the mine from which they were taken, as they came from solid coal under deep cover.

Waterloo Coal—Lord (Sampled by C. N. Brown).

No. 1. Charles Neal's.
No. 2. Thomas Cooper's.
No. 3. Russell Brothers.

	1.	2.	3.
Moisture	6.44	6.98	7.13
Volatile combustible matter	37.56	36.65	35.52
Fixed carbon	49.42	50.14	49.64
Ash	6.58	6.23	7.71
Total	100.00	100.00	100.00
Sulphur	1.16	0.57	0.56

These results are very gratifying and assuring. Although the moisture and ash are higher than in most of our best coals, they do not exceed the percentages in the Jackson Shaft seam. In sulphur, the Waterloo seam runs as low as any other Ohio coal, being very much freer than the coal of any other Freeport basin in the State. It is an open-burning seam, at least sufficiently so to give promise of its successful application to iron smelting, in the raw state. Actual trial is, of course, necessary to determine this adaptation, but it seems probable that this field is the one on which the failing iron manufacture of Lawrence county can depend for a new lease of life. No coal south of the Monday Creek field shows so little sulphur.

Several railroad surveys have been directed to the Waterloo Coal Field within the last few years, but none of them has advanced beyond the preliminary stages of road building. When the proper time comes, and proper facilities for distribution are secured, it is safe to predict that this last of the Upper Freeport basins of the State will make an important contribution to our coal supply.

CHAPTER XIX.

THE MEIGS CREEK COAL SEAM IN MORGAN, MUSKINGUM, GUERNSEY AND NOBLE COUNTIES.

By C. Newton Brown.

Through Morgan, Noble, south-eastern Muskingum and north-western Monroe counties, the most important coal horizon is found about 250 to 260 feet above the Ames or Crinoidal limestone, or about 80 to 100 feet above the horizon of the Pittsburgh coal. The areas occupied by the seam are indicated on the map which accompanies this volume (Map No. 9). The seam appears to be the Sewickley coal of the Pennsylvania series. In former reports this coal is known as the Upper Bellaire, Upper Barnesville or Cumberland coal. The term Cumberland is already occupied as the name of a famous Maryland coal, and it will therefore be dropped, as a confusing synonym, and the coal will here be designated the Meigs Creek coal from the name of the stream in Morgan county which drains a central portion of the field. For convenience of description this coal field will be divided into three districts.

The first includes western Morgan, and eastern and Central Athens, and Meigs counties. Here the Meigs Creek coal is thin and unsteady, and of little economic value.

The second includes eastern Morgan, Noble, south-eastern Muskingum and southern Guernsey counties. Here the Meigs Creek coal is the only coal that can be worked ina large way.

The third includes Belmont, north-western Monroe, eastern Harrison and southern Jefferson counties. Here the Meigs Creek coal is in good force, but it has to give way to the Pittsburgh seam, which is the thicker and much purer.

The character of the coal and its roof are surprisingly steady over the entire field.

The average of many analyses shows the following composition (Lord):

Moisture	3.10
Volatile combustible matter	40 to 41
Fixed carbon	44 to 45
Ash	11 to 11.5
Sulphur, very near	5.

This shows a coal very high in both ash and sulphur, and very low in fixed carbon. Such a coal can not successfully compete with coals having from 50 to 57 per cent. of fixed carbon, 3 to 7 per cent. of ash, and from 1 to 2 per cent. of sulphur. The roof is usually a tough shale, making, when properly treated, a very good cover. Sometimes there is a thin coal just above the main seam that is left for roof.

The coal is high enough to be drained without the use of machinery, but usually a layer of hard white limestone is found in drain trenches at 1 to 4 ft. under the coal.

The coal mines fairly well, and will bear considerable handling. Most of the mines visited were small country banks that were scarcely driven in beyond the outcrop coal. Through most of the second district there is a bone coal or tough streak, from 2″ to 6″ thick, near the center of the seam, which, if not carefully picked out, seriously injures the coal by increasing the ash and sulphur. Beginning on the Muskingum, and following the Meigs Creek coal south-west through the First district to the Ohio river, we find it often wanting, and at other places thin and of little value. It sometimes thickens to a few feet over one or two sections, but does not hold far. The coal crosses the Muskingum river at McConnellsville, Morgan county. It is here from 2½ to 3 feet thick, and is 250 feet above the Ames or Crinoidal limestone, and 82 feet above the Pittsburgh, which is here 28″ thick.

In the southern part of Malta township, Morgan county, the mark of the Meigs Creek coal is found on the highest ridges, but it has never been opened. The Pittsburgh coal is quite thin through this township.

Through Union township, Morgan county, the Meigs Creek coal is found as a strong coal mark, at 90 or 100 ft. above the coal, which is here reported 30 inches thick. There is a small coal found between the Pittsburgh and Meigs Creek coals.

Through Penn township traces of the Meigs Creek and higher coals are found, but neither of the seams has been opened.

Nothing of the Meigs Creek coal was found through Homer township, although the ground is high enough to hold it.

In the south-western part of Marion township, Morgan county, the Meigs Creek coal has been opened, and a thickness of 28 inches found. Near the south-eastern corner of Section 2, Marion township, the Meigs Creek seam shows the following section:

Sandstone	———
Shale	8 feet.
Bone coal, called cannel coal	3 inches.
Slate	2 "
Coal	15 "
Slate	2 "
Coal	6 "
Clay	———

The analysis of this coal is as follows:

Marion Township Coal (*Lord*).

Moisture	3.94
Volatile combustible matter	39.45
Fixed carbon	44.12
Ash	12.49
Total	100.00
Sulphur	4.97

The coal is quite high in ash and sulphur, but can be put to many uses.

Traces of a coal higher than the Meigs Creek coal are found in south-eastern Marion township, Morgan county, and eastern Bern township, Athens county.

In the southern part of Windsor township, Morgan county, the Meigs Creek coal has been opened at many places along the Muskingum river for local supply.

In lot 1114, Windsor township, Morgan county, the Meigs Creek coal measures as follows:

Shale roof	———
Bone coal	3 to 4 inches.
Slate	3 in.
Coal, slaty	8 in.
"Tough streak"	2 in.
Coal	18 in.
Clay	———

Trimble and Dover townships, of Athens county, have none of the Meigs Creek coal.

Ames township, Athens county, has the Meigs Creek coal in S. W. ¼ Section 24, on W. Kasler's land. It is 264 feet above the Ames or Crinoidal limestone, and has the following section:

Shale	———
Coal	12 inches.
Clay	18 to 24 in.
Coal	34 in.
Slate	1 to 2 in.
Coal	8 in.
Clay	———

This is the most western point of the Meigs Creek coal in northern Athens county.

The coal is found at Fr. Sec. 2, and Sec. 13, Bern township. At Fr. Sec. 2, it is reported 4 feet thick, and at Section 13 only 18 inches. At the latter place it is 119 feet above the Pittsburgh coal.

Athens township, Athens county, has the Meigs Creek coal in N. E. ¼ Section 4, but it is near the hill-tops, and the area of good coal quite small.

The Meigs Creek coal is found through most of Canaan township Athens county. In S. E. ¼ Section 23, it is 95 feet above the Pittsburgh coal, and in Section 33 it has in the past been mined.

It is opened on Mrs. Sam's farm, in S. E. ¼ Section 25, on the waters of Willow Creek. It here was 30″ thick; no partings noted. A few feet under the coal is found, through this township and on Long Run, a very thick ledge of sandstone. In the north-east part of Rome township, Athens county, several unsuccessful attempts have been made to find the Meigs Creek coal thick enough to mine.

The coal is well shown in a branch of Big Run, near the north side of Section 12, and in Section 18, Rome township, the coal is 125 feet above Federal Creek, and shows an outcrop 5 feet thick.

Alexander township, Athens county, is not high enough for the Meigs Creek coal, although the Pittsburgh seam is found throughout the eastern part of the township.

The coal has been found in northern Lodi township, Athens county, but nothing of it seen in the southern part. On Chas. Brown's farm in N. E. ¼ Section 30, Lodi township, the seam gives the following section:

Shale roof, good.		
Coal	28	inches.
Slate	12	"
Coal	4	"
Clay	12	"
Coal, exposed, 24 in., reported	36	"
Bottom, not exposed.		

There is a ledge of sandstone 60 feet thick under the coal. This is on Long Run. In Sections 12 and 18, the coal has been opened and found thin and unsteady.

In Fr. Section 12, and Fr. Section 3, Lodi township, marks of two higher coals were found—one at 235 feet, and the other at 100 feet above the Meigs Creek coal.

In neither Carthage nor Troy townships, Athens county, could the Meigs Creek coal be identified. A few faint marks, probably belonging to the upper coals, were seen, but no openings were found.

Through Meigs county the Meigs Creek coal seems to have entirely disappeared, as no trace of it could be found, although much of the county is above its horizon.

The second and most important district of the Meigs Creek coal includes that part of Morgan county east of the Muskingum river, south-eastern Muskingum, all of Noble and south-western Guernsey counties. Through this area the Meigs Creek coal is the only coal above drainage that can ever be mined in a large way. There is a large area of coal in eastern Morgan and western Noble counties, of 4 to 4½ feet thickness, that can easily be reached by railroads in the valleys of Meigs and Olive Green Creeks.

Bloom township, Morgan county, holds the Meigs Creek coal in the north-east part in quite a number of sections. It is here from 3½ to 4½ feet thick, with a characteristic parting or "tough streak" near the center of the stream.

On V. Savall's land, in N. W. ¼ Section 1, Bloom township, the coal measures 53 inches, including two thin partings. For the analysis of the coal see the following table.

The ash is unusually large, and the sulphur is above the average.

The coal on Wm. Barkhurst's land, in S. W. ¼ Section 26, Bloom township, gives a section that holds with little variation through the entire township :

Shale roof, stands fairly well.

Coal	18 in.
"Tough streak," or bone coal	4 in.
Coal	18 in.
Clay, about	2 ft.
White non-fossiliferous limestone	——

The Barkhurst coal was also analyzed (see below.)

Coal from Barkhurst's and adjoining banks is used in McConnellsville for ordinary domestic purposes. It is reported as making an enormous amount of ashes and clinkers when used in stoves. The analyses appended show the grounds for such charges.

Bloom Township Coal (*Lord*).

	1.	2.
Moisture	3.15	3.68
Volatile combustible matter	41.50	40.44
Fixed carbon	38.74	43.41
Ash	16.61	12.47
Total	100.00	100.00
Sulphur	5.73	5.74

No. 1. Savall's coal, Sec. 1, Bloom township.

No. 2. Barkhurst's coal, Sec. 26, Bloom township.

Morgan township, Morgan county, has the Meigs Creek coal in good force all through the eastern part, but it is thin in the river hills. It is mined for the McConnellsville market at a number of small banks in this township. It was measured on Abram Farris's land, in N. W. ¼ Section 35, T. 7, R. 12, Morgan township, also on F. Roberts and Alex. Offord's lands, in same section, and on R. Whipple's land, in Section 36, same township. In all these mines the coal ranges from 3 to 3½ feet, with a tough streak or bone coal of 3″ to 4″ at the center of the seam.

On E. Sherwood's land, in S. E. ¼ Section 19, T. 10, R. 11, Morgan township, the coal is found 36 inches thick, with no tough streak, but with 10 inches of poor coal at the top. The roof is shale, and stands well.

On the hill just east of McConnellsville, a section was measured showing the position of both the Pittsburgh and Meigs Creek coal with regard to the Ames or Crinoidal limestone.

The Meigs Creek coal is 250 feet above the Ames limestone, and 82 feet above the Pittsburgh coal, which is here 68 feet above the Ames limestone.

The Pittsburgh coal seems to be higher than usual—the lower interval being longer, and the upper one shorter than at other places.

The coal analyses as follows, in Morgan township:

No. 1. Abram Farris, N. W. ¼ Section 35, T. 11, R. 12.
No. 2. R. Whipple, S. W. ¼ Section 36, T. 11, R. 12.
No. 3. E. Sherwood, S. E. ¼ Section 19, T. 10, R. 11.
No. 4. Meigs Creek Coal, at Hooksburgh, Windsor township.

Morgan Township Coal (*Lord*).

	1.	2.	3.	4.
Moisture	4.20	3.75	3.85	3.93
Volatile combustible matter	38.65	40.55	36.72	40.84
Fixed carbon	43.83	44.02	42.43	46.49
Ash	13.32	11.68	17.00	8.74
Total	100.00	100.00	100.00	100.00
Sulphur	5.37	5.69	5.23	4.01

All of these coals are very high in both ash and sulphur, and low in fixed carbon. The ash is red, showing the sulphur to be combined with iron. The northern part of Windsor township, Morgan county, has the Meigs Creek coal, but not much of it is shown. The coal is opened in the north-east and north-west corners, but through the central part along the river the crop is probably so low as to be covered with the drift deposits of the valley.

The coal is worked at Hooksburgh in the north-west corner of the township. On Jas. Noyes' land, in lot 75, Windsor township, the coal is worked for the village use. The coal is hard and bright, and is in every way a promising coal in appearance. It measures 3 feet, with a small irregular slate near the center of the seam. The analysis of this coal has been given above. The analysis shows a better coal than either the Bloom or Morgan township coals. In the north-east corner of the township, on Olney Run, and about the mouth of Meigs Creek, the coal is found from 3 to 3½ feet thick, and quite low in the hills. In lot 33, Windsor township, on Mummeys' land, there is the best showing of an upper coal found in this entire coal field. It is

near the top of the highest ridge, and must be from 210 to 250 feet above the Meigs Creek coal. No reliable measure could be had. The coal gives a section very like the Meigs Creek coal; it is as follows:

Clay shale roof, very poor.	
Coal	16 in.
Slate and bone coal	8 in.
Coal	24 in.
Clay	——

This is probably a local thickening of one of the upper coals usually found as a mere mark or blossom. This is the only opening found in the high coals.

The Meigs Creek coal is due in all parts of Meigsville township, Morgan county, except when cut out by the creek valleys.

In the extreme south-east corner, in Sections 35 and 36, the coal is from 3 to 3½ feet thick, and near the level of the creek valleys. It is a little thin and irregular in the southern part of the township, but in the northern part is steady and in its usual thickness.

In S. W. ¼ Section 26, Meigsville township, on Hooper's land, the coal was worked one winter, but found thin, and abandoned. In N. W. ¼ Section 5, the coal has been opened, and reported a solid seam of 2 to 2½ feet. Through the northern part of Meigsville township two small coals are found below the Meigs Creek coal—one at 55 feet below, and 12″ to 20″ thick, and the other 81 feet below the Meigs Creek, and found 20 inches thick.

The lower one is probably the representative of the Pittsburgh seam. On Chas. Walker's land, in S. E. ¼ Section 1, Meigsville township, the coal gave the following section:

Sandy shale.		
Slaty coal left for roof, stands well	9	inches.
Clay	3	"
Coal	26	"
Slate or tough streak	4	"
Coal	26	"
Clay	—	

The analysis given below shows a coal much better than the average of this seam. There are a few clay veins found in this mine, but they are neither large nor frequent. The Meigs Creek coal is unusually free from such disturbances as clay veins and horsebacks.

On Walker's land a bank of cinders and clinkers found by the coal

burning into the hill has attracted considerable attention as a bed of iron ore. It can be of no value as an ore. Near Unionville, on J. W. Barkhurst's land, the Meigs Creek coal is mined, but it is not quite as thick as the Walker coal. The analysis is given below. It is unusually high in ash.

Meigsville and Bristol Coal (Lord).

	1.	2.	3.	4.
Moisture	2.57	2.98	3.03	4.62
Volatile combustible matter	41.50	37.17	42.03	33.33
Fixed carbon	46.65	43.55	45.59	42.41
Ash	5.28	16.30	9.35	19.64
Total	100.00	100.00	100.00	100.00
Sulphur	4.30	4.50	5.19	2.64

No. 1. Chas. Walker's coal, S. E. ¼ Section 1, Meigsville township.

No. 2. J. W. Barkhurst's coal, Section 13, Meigsville township.

No. 3. Average of four analyses in Bristol township.

No. 4. "Tough streak," from Jos. Reed's, Section 31, Bristol.

Through Bristol township, Morgan county, the Meigs Creek coal lies high in the hills, and the broad valleys of Meigs Creek and Mann's Fork, of Meigs Creek, have cut out large areas of it. The "tough streak" is very persistent over the entire township, ranging from 1″ to 4″, and the entire seam from 3 feet to 4½ feet.

On the land of Webb Lawrence, in S. W. ¼ Section 20, Bristol township, the coal is in two benches—the upper, 20 in. thick, the lower, 24 in., and a 4-inch "tough streak" between, making the full seam just 4 feet. This is the usual section of the coal through the entire township. The average of four analyses is given in the above table. The analyses show the coal to have a lower per cent. of ash, but a higher per cent. of sulphur than the average of the seam. A sample of the "tough streak" was taken at the mine of Jos. Reed, in S. W. ¼ Section 31, Bristol township. The coal was 3½ feet thick, with 6 inches of tough streak near the center of the seam. The analysis of the tough streak is given above.

The ash of the Meigs Creek coal is usually red, but sometimes has a tinge of purple. The coal usually makes clinkers in stoves.

Over the coal, 55 feet below the Meigs Creek coal, there is frequently a sandstone that furnishes good building stone.

The greater part of Manchester township is underlaid by the Meigs Creek coal in its best development. The coal is rather low in the hills, so that the creeks have not cut away a great deal of it. Meigs Creek, through the central part, Brannon's Fork, through the north-west corner, and Olive Green Creek, through the south-east part, furnish every facility for reaching all parts of the coal with railroads.

The coal is here usually known as the five-foot seam, but no measures we found over 4½, although there may be such. The thick tough streak is replaced by a thin clay parting near the center of the seam. On Dan. Fowler's land, in S. W. ¼ Section 29, near Reinersville, the coal gives the following section and analysis, which may be taken as representative of the entire township:

Clay shale roof.	
Coal	24 in.
Clay parting	1″ to 2″.
Coal	26″ to 27″.
Clay	5 feet.
Limestone	—

At other places in the same mine the entire seam measured a little over 4½ feet. The analysis is as follows (Lord):

Moisture	2.42
Volatile combustible matter	42.35
Fixed carbon	46.20
Ash	9.03
Total	100.00
Sulphur	4.64
Specific gravity	1.382

Centre township, Morgan county, has a larger area of the Meigs Creek coal than any other township in Morgan county. The coal is low in the hills, and Big and Little Olive Green Creeks cut only narrow valleys through it.

The coal has been opened on almost every farm about Center Bend and up Olive Green Creeks. On John Wainright's land, in S. E. ¼ Section 28, Centre township, the coal is in two benches—an upper one of 6 inches, and a lower one of 24 inches, with a 3-inch bone coal between. The analysis of this coal is given below. In the S. E. ¼ Section 30, Centre township, on L. Andrews' land, the Meigs Creek coal is found to be a fair cannel coal. The seam is thin here, as only 2 feet of coal was found. There was no parting.

The coal was hard and bright, and makes red ashes.

In S. E. ¼ Section 19, Centre township, a section showing the strata above the coal was measured as follows:

Shale, exposed	2 feet.
Non-fossiliferous limestone	4 "
Hard sandy shale	9 "
Non-fossiliferous nodular limestone	2 "
Sandy shale	2 "
Sandstone	2 "
Shale, gray at top, and blue at bottom	12 "
Coal	15 in.
Bone coal and slate mixed	9 in.
Coal	21–24 in.
Clay	———

The bone coal and slack are here used for burning lime, which is done in open piles.

In N. W. ¼ Section 26, the coal goes under Olive Green Creek, and the dam of Moscow Mills is built upon it. From this to the south and east the coal is below drainage, but to the north and west it soon gets above the creek.

On John Henderson's land, in S. W. ¼ Section 23, the coal is 5 feet above the creek, and has two benches—an upper one of 19 inches, and a lower one of 21 inches, with 3 inches of slate and bone coal between.

In N. E. ¼ Section 23, Centre township, a section was measured, including two coals above the Meigs Creek coal. The higher is, by barometer, 245 to 255 feet above the Meigs Creek coal, and the lower is, by hand-level, 156 feet above the Meigs Creek coal. Neither of them was found opened.

At this and some other points in Central township a thick sandstone from 20 to 30 feet thick is found a few feet above the coal, and quite frequently a thick sandstone was noticed close under the coal.

On the land of R. W. Combs, in S. E. ¼ S. W. ¼ Section 9, Centre township, the Meigs Creek coal is mined for the local supply and lime-burning.

It here has two benches, separated by a black slate of 4 inches. The upper bench is 13 inches, and the lower 30 inches (see the analysis below). In this mine a few clay veins are found, but are neither large nor frequent enough to be of serious trouble:

Center Township Coal (Lord).

	1.	2.
Moisture	3.00	2.35
Volatile combustible matter	40.83	41.67
Fixed carbon	45.75	43.38
Ash	10.42	12.60
Total	100.00	100.00
Sulphur	5.35	5.69

No. 1. Jno. Wainright's, S. E. ¼ Section 28, Centre township.
No. 2. R. W. Combs, in S. W. ¼ Section 9, Centre township.

The Meigs Creek coal is found in the tops of the highest ridges in the eastern part of Blue Rock township, Muskingum county. The area of first quality coal is small, as it is so near the hill-tops; the covering is thin and light. The coal is opened on Hunter's land, in S. W. ¼ Section 26, Blue Rock township, near Rural Dale, where it is nearly 4 feet thick, with a parting near the center.

The coal is opened on a number of farms in the vicinity.

Meigs township, Muskingum county, has a large and valuable area of this coal. It connects with the coal in Bristol and Manchester townships, of Morgan county, and with Brookfield, of Noble county. On Howell's land, in S. E. ¼ Section 8, Meigs township, the Meigs Creek coal is found 39 inches thick, in three almost equal benches, having slate partings of an inch between them.

In the N. E. ¼ Section 9, Meigs township, Muskingum county, the Meigs Creek coal gives the following section:

Clay shale.		
Rotten coal	24	inches.
Clay	20	"
Coal	18	"
Slate	1	"
Coal	16	"
Slate	1	"
Coal, exposed	18	"
Bottom, not exposed.		

On Paisley's land, in S. E. ¼ of same section, the seam shows the same structure, except that the lower parting is 6 inches thick, and the upper parting is nearly lost.

In Section 9, Meigs township, hand-level measures were had to coals both above and below the Meigs Creek seam. The section is as follows:

Coarse sand stone	25 to 30 ft.
Clay shale	1 to 2 ft.
Coal, reported	18″ to 24 in.
Not exposed	128 ft.
Meigs Creek coal	4 ft.
Not exposed	88 ft.
Coal, reported	30 in.

Both upper and lower coals had been opened. The lower is probably the Pittsburgh seam. The seam was reported to hold 30″ of solid coal.

On John Lett's land, in N. E. ¼ Section 26, Meigs township, the Meigs Creek coal is benched in the creek bank. It is used by all the country blacksmiths for several miles around. The coal is in three benches, separated by inch partings. The upper bench is 16 inches, the middle, 12 inches, and the lower, 24 inches.

The Meigs Creek coal is found in the high ridge extending north through Rich Hill township, Muskingum county, and dividing the waters of Wills Creek from those of the branches of Salt Creek. The coal area is small and of little value, except for local supply.

In Sections 21 and 22, Rich Hill township, measurements were had, showing the position of the two coals and Ames limestone, as follows:

Meigs Creek coal	4½	ft.
Not exposed	81	ft.
Pittsburgh coal	30	in.
Not exposed	151	ft.
Ames or Crinoidal limestone, about	2	ft.
From the Ames or Crinoidal limestone to the Meigs Creek coal is	232	ft.

At the portals of the B., Z. & C. R. R. tunnel, in Section 22, Rich Hill township, a good section, showing the strata above and below the coal, is furnished:

Soil.		
Soft shale	12	feet.
Black slate	6	inches.
Clay, or clay shale	15	"
Slaty coal	5	"
Parting	½	"
Coal	23	"

Hard slaty coal	5 inches.
Black slate	7 "
Coal	9 "
Clay	30–36 "
Limestone, non-fossiliferous	1 ft.
Clay	4 ft.
Solid limestone, non-fossiliferous	16 ft.

At Rixville, in Section 3, Rich Hill township, on John Smith's land, the coal is worked for a steam mill. The coal is 49 inches thick, and has a 3-inch clay parting, 24 inches from the top, and 7 inches of slaty coal, 10 inches above the bottom. The analysis of the Rixville coal is herewith given:

Rixville Coal (*Lord*).

Moisture	4.04
Volatile combustible matter	39.59
Fixed carbon	44.58
Ash	11.79
Total	100.00
Sulphur	3.81

At Rixville the Pittsburgh coal has been opened at 82 feet below the Meigs Creek coal, and found 30 inches thick. A solid seam with no partings.

The Meigs Creek coal is found a few miles north of Rixville, in Union township, Muskingum county, in small outliers, but the coal is of little value.

The coal also follows a ridge east from Rixville, into Westland and Spencer townships, Guernsey county. It is found only in the extreme south-western corner of Westland township, Guernsey county, and is very high in the ridge. It was reported from 3½ to 4 feet, with a parting near the center. Spencer township, Guernsey county, has more of the Meigs Creek coal than any other township of Guernsey county The coal is found in a high ridge, north of Cumberland, running east between two forks of Wills Creek. In the N. E. ¼ Section 29, Spencer township, the coal is 48 inches thick, with a clay parting 1 to 2 inches, 13 inches below the top, and a 3-inch bone coal, 9 inches above the bottom. The lower 8 inches of the middle bench is rather slaty and poor.

Ohio Geological Survey, Vol. V — Edward Orton, State Geologist.

No. 9.

MAP OF THE MEIGS CREEK COAL FIELDS IN PART, IN MUSKINGUM, MORGAN, NOBLE AND GUERNSEY COUNTIES.

A soft, coarse sandstone is here found a few feet above the coal, which is quarried and crushed, and used for building sand in Cumberland. Most of the coal used in Cumberland is mined just to the south in the edge of Brookfield township, Noble county. It is from this particular field that the name Cumberland was applied by Professor Andrews to the seam. Every township of Noble county, except Buffalo, holds the Meigs Creek coal. The best areas are in the western and southern parts of the county. The broad valleys of the West Fork, of Duck Creek, in the Central part, and of Buffalo, Seneca and Beaver Forks, of Wills Creek, in the northern part, cut out large areas of the seam.

The seam will average for the entire country very nearly 4 feet. It is often reached 5 feet, but also frequently comes down to 2½ and 3 ft.

In several townships a "roof coal" from 12″ to 18″ is found, 6″ to 18″ above the main seam. In this it resembles the Pittsburgh coal through Belmont county.

The Meigs Creek coal still holds its high per cent. of ash and sulphur through all Noble county; Brookfield township, Noble county, holds the Meigs Creek coal in all parts, except the extreme northeastern corner.

In the eastern and northern parts, the coal is high in the hills, while in the southern and western parts it is only a few feet above the creek valleys. In the S. W. ¼ Section 4, Brookfield township, on H. C. Hunter's land, the coal gave the following section:

Hard shale, good roof.		
Coal	11	inches.
Slate parting	1–2	"
Coal	16	"
Clay, or slate parting	2	"
Coal	12	"
Hard slate with ferriferous sandstone	¼–½	"
Coal	12	"
Clay	—	

On Geo. McEndrie's land the same coal is mined, and gives practically the same section. These mines furnish a greater part of the coal used in Cumberland. At about 30 to 40 feet below the coal, in northern Brookfield township, there is a ledge of fine-grained, tough sandstone that makes an excellent building stone. The ledge is about 15 feet thick. These quarries furnished the main supply of stone for Guernsey

county court house, in Cambridge. The Meigs Creek coal has been stripped in the bed of Meigs Creek, in the center of Section 18, and has been mined at 15 to 18 feet above the creek valley, in S. W. ¼ Section 30, Brookfield township.

The coal has at some time been opened on almost every farm that has its crop, but the mines are not kept in a condition to be entered.

At John Dickson's steam mill, in N. W. ¼ Section 31, Brookfield township, the coal gave the following section:

Clay shale roof, poor.		
Coal	6	inches.
Clay parting, often full of ferriferous sandstone	½	"
Coal	13	"
Hard slate, full of ferriferous sandstone	½	"
Coal	28	"
Clay	—	

The total seam is here 4 feet. It is reported as often reaching 4½ feet, and sometimes 5 feet.

On the land of John A. Thrap, in N. W. ¼ Section 22, Brookfield township, the Meigs Creek coal gives the following section:

Clay shale roof, poor.		
Coal, slaty and poor	6	inches.
Clay parting	1	"
Coal	15	"
Hard slate parting	½	"
Coal	11	"
Black slate	2	"
Coal	13	"
Clay	—	

The partings do not seem to be as well-defined and characteristic as in Morgan county, but come and go in all parts of the seam.

The average of three analyses from Brookfield township is as follows:

Brookfield Coal (Lord).

Moisture	3.41
Volatile combustible matter	40.30
Fixed carbon	45.41
Ash	10.88
Total	100.00
Sulphur	5.31

In the S. W. ¼ Section 18, Brookfield township, the mark of a higher coal was found. The distance above the Meigs Creek coal could not be accurately determined, but it was, by barometer, near 215 feet. The blossom would indicate at least 2½ feet of coal.

Many years ago this high coal was opened, and taken to Cumberland for making coke; but the thinness of the seam, and the long distance to the railroad, caused it to be abandoned.

In Sections 9 and 16, same township, a coal mark was found at 160 to 180 feet above the Meigs Creek. No openings into it could be heard of. Nothing was seen of any coals below the Meigs Creek coal.

In Buffalo township, Noble county, nothing could be found of the Meigs Creek coal, as the land is all too low for it. It is possible that there are a very few outliers of the coal in the tops of some of the highest points in the south-east corner of the township, but if there should be, they would be of no practical value.

Noble township, of Noble county, has very little of the Meigs Creek coal. There are a few outliers in the east central part and south-west corner. No openings could be found in the eastern one, but several of the western ones have been worked for local supply.

At Hiramsburgh, in Section 13, Noble township, a small outlier is worked for the villagers' and farmers' use. The coal is here from 4 to 4½ feet thick, and by hand-level, 258 feet above the Ames or Crinoidal limestone.

The place for the Pittsburgh coal was passed in this section, but nothing found of it. The Meigs Creek coal at Hiramsburgh makes a large amount of red ashes, and some clinkers.

Sharon township, Noble county, holds a very large area of the Meigs Creek coal. In the eastern part the coal is well up in the hills, but in the southern and western parts the coal is low, and little of it carried away by the creek.

The coal thickens from 3 to 3½ feet in the northern part of the township, to 4 and 4½ feet in the southern parts.

The roof is usually bad, and all entries have to be thoroughly timbered, and the rooms driven narrow and well posted. The ribs should be left thick.

No sections of the coal could be had in this township. Nothing was seen of the thin coals below the Meigs Creek coal, but the mark of the thin coal, at 160 to 170 feet above, was found in Sections 3 and 10, Sharon township.

A fine-grained sandstone was noticed at 30 to 40 feet below the Meigs Creek coal, which furnishes good flagging and building stone.

Olive township, Noble county, holds the Meigs Creek coal in the eastern and western parts, but through the central part the coal has been cut out by the deep, broad valley of the West Fork of Duck Creek.

The eastern area is made up of a few outliers and narrow strips in the tops of the ridge. The western area is found in the water shed between West Fork of Duck Creek, and Big Olive Green Creek, and although high in the ridge, there is a good area of solid coal.

No worked mines were found on the western side, but from reports of the abandoned ones the coal is thin, except in the extreme southern part of the township.

Near the N. W. corner of the township an old mine was reported 2½ to 3 feet, rarely 3½ feet thick. In Section 28, Olive township, 3 feet was given as about the average, with a "tough streak" of 3″ to 4″ near the top of the seam. In Section 35, Olive township, the coal was said to be from 3′ 9″ to 4′ thick, with a "tough streak" near the center of the seam.

On the land of Ezra Davis, in N. E. ¼ Section 13, Olive township, the Meigs Creek coal gave the following section:

Clay shale roof, fair.		
Hard, black raw slate	2	inches.
Coal	12	"
Hard, black slate	½	"
Coal	21	"
"Tough streak"	3	"
Coal	24	"
Clay	—	

The entries do not have to be timbered, and the rooms are run 20 to 24 feet wide, with two rows of posts.

In the S. W. ¼ Section 12, Olive township, the coal is thinner, measuring only 3 to 3½ feet, with a "tough streak" at the top. The roof is also poor.

Jackson township, Noble county, has the largest area of the Meigs Creek coal of any township in Noble county. Only the largest creeks cut down through the coal, and they only take out very narrow strips. In the north-eastern corner of the township the coal is well up in the hills, but it drops rapidly to the south and west, and soon comes close to the level of the valleys.

In the N. E. ¼ Section 12, Jackson township, the Meigs Creek coal gives the following section. No regular parting could be made out, so none is given:

Shale.	
Coal, poor	18–24 in.
Clay	14–18 in.
Coal, measured from	4 ft. 4½ in.
Clay	—

On Wm. Taylor's land, in S. W. ¼ Section 10, Jackson township, the Meigs Creek coal was measured as 5½ feet, and was reported as 6′·2″ in one part of the mine. The coal here makes gray ash, and no clinkers.

On Keith's land, in N. W. ¼ Section 8, Jackson township, the coal gave the following section:

Clay shale roof, poor.	
Coal, measured from	3½–4 ft.
Clay	1–3 in.
Coal, left for bottom	4–6 in.
Clay	—

On Reasoner's Run, in Section 19, Jackson township, a thick sandstone comes down on top of the coal, which is here from 3′ 8″ to 4′ thick. Above the sandstone comes a thick, white, non-fossiliferous limestone.

In Section 25, Jackson township, on Cat Run, traces of a coal, 50 to 60 feet below the Meigs Creek coal, were found, and in Sections 28 and 33 traces of two upper coals were found—one at 250 and the other at 162 feet, by barometer, above the Meigs Creek coal. The highest one is 18″ thick, and the thickness of the other not known. On the land of John E. Williams, in N. E. ¼ Section 34, Jefferson township, Noble county, the Meigs Creek coal shows the following section:

Limestone.		
Bone coal	6	inches.
Coal	8	"
Slate	1	"
Coal	14	"
Slate parting	½	"
Coal	12	"
Clay	12–18	"
Coal	16–22	"
Parting	2	"
Coal	24	"
Clay	2′–4	"
Limestone, exposed	2 ft.	

The roof coal is here unusually well developed, and is taken down and used with the regular seam. There is a large portion of Jefferson township with the Meigs Creek coal, but little of it is as thick as the last section. The roof coal seldom exceeds 18″ or 20″ at other places.

On the lands of Hugh Robinson, in S. W. ¼ Section 13, T. 6, R. 7, Elk township, Noble county, the Meigs Creek coal was measured as follows:

Hard shale.		
Coal	30	inches.
Clay	12	"
Coal	14–15	"
Bone coal	4	"
Coal	13	"
Slate parting	¼–½	"
Coal	18	"
Clay	2–4	feet.
Limestone	16	feet.
Shaly sandstone	—	

There is a large area of the Meigs Creek coal in Elk township that could easily be reached by railroads traversing the East Fork of Duck Creek.

The Meigs Creek coal is reported to be the same as the Stafford coal of Monroe county, but this was not investigated. There is a thin coal, about 60 feet below the Meigs Creek coal, through the northern part of the township.

In Enoch township, Noble county, the coal is high in the ridges, and the area of first quality coal therefore smaller than that of Jefferson and Elk townships.

The Meigs Creek coal is found in two ridges, with their spurs running north-west and south-east through the township, and dividing the waters of the West Fork, Middle Fork, and East Fork of Duck Creek.

No section could be found in Enoch township, but the coal was nowhere reported over 4 feet thick. A sample from the mine of Wm. Lincicome, in S. E. ¼ Section 32, Enoch township, gave the following analysis:

Enoch Township Coal (Lord).

Moisture	2.18
Volatile combustible matter	41.75
Fixed carbon	45.92
Ash	10.15
Total	100.00
Sulphur	4.02

The characteristic high per cent. of ash and sulphur still hold good.

The Meigs Creek coal, in south-west Enoch and West Jefferson townships, touches the Cleveland and Marietta R. R. (now Wheeling and Lake Erie), and was formerly mined for shipping on the railroad, but has now been abandoned, and all the works and tracks taken out.

In the S. W. ¼ Section 25, Stock township, Noble county, on Wm. Taylor's land, the Meigs Creek coal gave the following section :

Clay or soft clay shale.		
Coal	13	inches.
Slate parting	1	"
Coal	16	"
Bone coal and slate	4	"
Coal	26	"
Clay	—	

The coal in Stock township is well up in the hills, and the broad valley of East Fork of Duck Creek has cut out a large amount of it. Over the entire township the coal ranges from 3½ feet to 5 feet, averaging probably 4 feet or a little over.

Center township, Noble county, has the Meigs Creek coal in the tops of the high ridges in the eastern part. The area of marketable coal is comparatively small, but will for many years supply the local demand.

The coal is reported as averaging about 4 feet thick, but no section could be had. In the eastern part a thick sandstone comes in a few feet above the coal, and is quite steady for an area of several miles.

Marion township, Noble county, holds considerable Meigs Creek coal, although it is well up in the hills.

The Meigs Creek coal, on W. H. Craig's land, in N. W. ¼ Section 1, Marion township, measures as follows:

Shale.		
Roof coal	18–24	inches.
Clay shale	18	"
Coal	12	"
Slate	½–1	"
Coal	12	"
Bone coal or tough streak	5	"
Coal	17	"
Clay, from	1–3 ft.	
Limestone	—	

In the B., Z. & C. Railroad cut, in Freedom, in S. E. ¼ Section 2,

Marion township, a section of a coal 113 feet, by barometer, above the Meigs Creek coal, was measured as follows:

Soil.	
Soft, shaly sandstone	4 ft.
Soft clay shale, blue and yellow	10 ft.
Coal	12 in.
Clay	5 in.
Coal	5 in.
Clay	—

About Freedom, and in the west part of Marion township, a thick ledge of sandstone is often found from 2 to 4 feet above the Meigs Creek coal, and often 40 feet thick.

In the ridge, running north from Summerfield, although high enough, the coal is reported as often wanting, and as always thin when found.

On Wm. Craig's land, in N. E. ¼ Section 13, Marion township, the Meigs Creek coal is mined and measured as follows:

Shale.		
Roof coal	20–24	inches.
Clay	18–24	"
Coal	4–6	"
Clay parting	½	"
Coal	24	"
Bone coal or slate	2–3	"
Coal	20–22	"
Clay	2–4	feet.
Limestone in layers, with shale between	10 ft., exposed.	

This coal was analyzed with following result:

Marion Township Coal (*Lord*).

Moisture	1.86
Volatile combustible matter	39.63
Fixed carbon	45.92
Ash	12.59
Total	100.00
Sulphur	6.10
Specific gravity	1.376

It was reported by the miners that in parts of this mine the roof coal was replaced by a white non-fossiliferous limestone, the clay

between the roof coal and the main seam being found all regular between the white limestone and the regular seam.

The coal is opened and worked for winter supply on almost every farm through the township, and is seldom found under 4 feet in thickness. Although the coal is well up in the hills, it can easily be reached by railroads, as the B., Z. & C. R. R. crosses the ridge far above the coal. The Bellaire, Zanesville and Cincinnati Railroad is a narrow-gauge, and just finished from Bellaire to Zanesville.

Seneca township, Noble county, has very little of the Meigs Creek coal. It is found only in the highest ridge in the township. The ridge between Beaver Fork and Seneca Fork of Wills Creek holds quite a large outlier, which furnishes coal for the adjoining farmers.

The dividing ridge between Seneca Fork and Buffalo Fork of Wills Creek holds the largest area of the coal in the township. This is worked near Mt. Ephraim, in the mine of Sam'l McConnell, in N. W. ¼ Section 33, Seneca township, and gives the following section:

Hard shale.		
Bone coal, or hard black slate	16	inches.
Good coal	8	"
Clay shale	8–18	"
Coal	10	"
Parting	½–1	"
Coal	15	"
Parting	1–2	"
Coal	20	"
Clay	—	

The roof coal is left for roof, the clay shale being taken out of the entries, and in the rooms it is thrown back as it falls down.

No higher coal marks were found. A very faint mark of the Pittsburgh coal was found at one place only.

Wayne township, Noble county, has only a few outliers of the Meigs Creek coal in the N. E. corner. The coal is in the very top of the hills, and, as far as could be learned, rather thin.

The coal has been opened in S. E. ¼ Section 21, and in N. W. ¼ Section 28, Wayne township. The coal in both cases was reported as about 3 feet thick.

A faint coal mark was seen at 50 to 55 feet below the Meigs Creek coal, but nothing found of the Pittsburgh coal, which ought to be a little lower.

A few feet below the Meigs Creek coal is a thick sandstone, which

is quite steady in the north-east part of Wayne township, and in north-west part of Beaver township. The northern and southern parts of Beaver township have considerable of the Meigs Creek coal, while the central part has been all cut away by Beaver Fork of Wills Creek, running west through the township.

On the land of H. C. Reed, in S. E. ¼ Section 17, Beaver township, the Meigs Creek coal is mined for the Williamsburgh market.

Reed's coal gives the following section :

Sandstone.	
Shale	18 inches.
Coal	16 "
Clay	16 "
Slate	2 "
Coal	30 "
Clay parting	2 "
Coal	24 "
Clay	2–4 feet.
Limestone	—

It is reported that several years ago a coal from 3 to 4 feet thick was dug out of the creek bed, at 92 feet below Reed's coal bank. The lower coal was looked for farther to the south and west, but never found. If the statement be true, we are here upon the western edge of the valuable area of Pittsburgh coal, extending eastward to the Ohio river.

In Section 1, Beaver township, the Meigs Creek coal was reported 3 feet thick. In the N. W. ¼ Section 8, a strong coal mark was found 90 to 100 feet above the Meigs Creek coal. No openings could be found into the upper seam.

On Wm. Lashley's land, in S. W. ¼ Section 26, Beaver township, the Meigs Creek coal was found 4½ feet thick, with two thin partings dividing the seam into three nearly equal parts. The roof coal was from 18″ to 24″ thick, and is 6″ to 12″ above the main seam ; the two separated by clay.

At Barnesville, Belmont county, the Meigs Creek coal, or as here known, the Upper Barnesville coal, is worked by means of a shaft, some 70 feet deep.

The shaft formerly went down to the Pittsburgh coal, but the lower part has been abandoned and filled up to the level of the Meigs Creek coal. The coal here gives the following section :

Shale.		
Roof coal	8	inches.
Clay, or "soapstone"	18-24	"
Black slate	2-6	"
Coal	6	"
Slate parting	2	"
Coal	19	"
Slate parting	$\frac{1}{4}$–$\frac{1}{2}$	"
Coal	15	"
Clay	—	

The Upper Barnesville coal gives the following result, when analyzed:

Upper Barnesville or Meigs Creek Coal (*Lord*).

Moisture	2.09
Volatile combustible matter	40.05
Fixed carbon	47.77
Ash	10.09
Total	100.00
Sulphur	2.98
Specific gravity	1.345

The ash is still high, but the sulphur is far below the usual per cent. for the Meigs Creek coal. This mine is now worked only in a small way, furnishing a part of the coal for the town of Barnesville.

The layer of clay or "soapstone" between the main seam and the roof coal makes the mining of this coal more expensive and dangerous than it would otherwise be. The soapstone is very wet, and is full of "slips" or "faults," and should be taken down with the coal, or immediately after. It forms a very treacherous roof when left up.

Going west along the Central Ohio Railroad, from Barnesville to Quaker City, Guernsey county, a fair barometer section can be had of the upper coals down to the Ames or Crinoidal limestone.

The distances from the bottom of the Pittsburgh coal are as follows:

Coal, 18″ thick, in railroad cut, at Barnesville	200–210	feet.
Coal, 6″ thick, in railroad cut, west of Barnesville	153	"
Coal, Upper Barnesville	100	"
Bottom of Pittsburgh coal	0	
Ames, or Crinoidal limestone, below	140–160	"

This would make the Meigs Creek, or Upper Barnesville, at 240 to 260 feet above to Ames or Crinoidal limestone. The Upper Barnes-

ville coal is mined at the foot of the hill, just to the north of Barnesville.

In Section 17, of Warren township, Belmont county, a section, showing the relative position of four coals was measured as follows:

Upper Barnesville coal, 3 ft. shown, 96 feet above Pittsburgh seam.
Coal, about 1 ft. shown, 72 feet above Pittsburgh seam.
Coal blossom, 28 feet above Pittsburgh seam.
Bottom of Pittsburgh coal, 5 feet thick.

The two coals between the Pittsburgh and Upper Barnesville are not known to be at any place of workable thickness.

On the Cleveland, Lorain and Wheeling Railroad, at Flushing, Belmont county, the Flushing Coal Co., operated by O. Young & Co., of Elyria, have mined the Meigs Creek, or Upper Barnesville coal for the general market, to some extent, but the mine is now closed. This was the only mine in the Meigs Creek seam from which coal has been recently shipped by rail. The coal gives the following section:

Sandy shale.	
Hard, brown slate	12–18 inches.
"Soapstone," full of slips, and very treacherous	9–15 "
Coal, solid seam, from	3′3″–4′2″.
Clay	—

This coal gives the following analysis:

Flushing Coal (*Lord*).

Moisture	3.18
Volatile combustible matter	38.31
Fixed carbon	50.10
Ash	8.41
Total	100.00
Sulphur	1.78
Specific gravity	1.300

This coal shows a much better composition than most of the Meigs Creek coal. The ash is much lower than usual, while in sulphur it will compare favorably with many other Ohio coals. The "soapstone" is a clay that is usually wet, and always full of slips or "kettle bottoms," which make it dangerous to work under it. It is, therefore, taken down with the coal, or usually just after, to prevent mixing it with the coal. The hard slate above then forms an excellent roof.

The mine, during 1883, put out 7 to 8 car loads of lump and 1 of

nut coal per day. The Upper Barnesville coal is shown in the west end of the Flushing tunnel, on the C., L. & W. R. R. The section is as follows:

Shale, up to soil, about	15	feet.
Coal	4	"
Clay	1½	"
Shale, to bottom of tunnel	2½	"

At the east end of the tunnel the coal is below grade, and does not show for some distance east of the tunnel. No solid rock appears in the deep cut at the entrance to the tunnel.

About Bellaire the Meigs Creek, Upper Barnesville, or Upper Bellaire coal is found, 4 feet thick, and 80 to 95 feet above the bottom of the Pittsburgh coal. Although the Upper Bellaire coal is 4 feet thick, and as easy to get at as the Pittsburgh seam, it is not mined at all, and very little account is made of it. The thicker and better Pittsburgh coal meets all demands.

In Washington township, Belmont county, on the B., Z. & C. R. R. (narrow-gauge), the Captina Coal Co. has a shaft to the Pittsburgh coal. The Upper Bellaire, or Meigs Creek coal, is here found 98 feet above the bottom of the Pittsburgh coal. It is reported 4 feet thick, and of the usual Meigs Creek coal character. It formerly supplied the local market, but since the Pittsburgh coal has been available the mines in it have been abandoned, and, therefore, no section could be had.

The Meigs Creek coal was found in the high ridges in the eastern part of Harrison county.

The Pittsburgh coal is in good force through this region, and, therefore, there is little regard for the thinner and poorer seam that lies above it. The coal is reported from 3 to 4 feet thick, but no sections were found. The coal is from 90 to 95 feet above the Pittsburgh coal.

The Meigs Creek coal is also found in the south-west corner of Jefferson county. It is here near the hill-tops, and thinner than usual, and is not worked. The Pittsburgh coal is of usual thickness and quality through this area.

NOTE.

I regret very much that lack of time for the preparation of reports and lack of space for publication, alike forbid any further statements as to the coal seams of the Barren and Upper Coal Measures of the State.

The field which has been treated in the preceding chapter is intrinsically much

less valuable than the Pittsburgh coal field in Ohio, but inasmuch as the latter is already extensively occupied and developed by mining industries, and consequently is well known as to character and capacity, I have judged it best to use the few pages of space available in the present volume for the upper coals, in a description of the comparatively unknown and undeveloped seam, the extent and character of which have now been briefly indicated. Mr. Brown's map and report show very clearly the areas, thickness and quality of this seam, and few questions in regard to the field are left unanswered, so far as its availability for mining operations is concerned.

A large amount of information has been gathered by the present Survey in regard to the coal seams above the Mahoning sandstone, but inasmuch as the volume has already passed beyond proper limits, not even a summary of these results can be furnished here. E. O.

CHAPTER XX.

REPORT OF CHEMICAL DEPARTMENT.

By N. W. Lord, Chemist of the Survey.

In completing the present volume a large amount of chemical work was called for, especially in the newer portions of the mineral field. The analyses for the present survey were all made under my direction in the laboratory of the Mining Department of the State University at Columbus, during the last two years.

In this connection I wish particularly to acknowledge the efficiency and accuracy of my assistant, Mr. Willis J. Root, in whose hands the larger part of the laboratory work was placed, to whose skill as an analyst, I take pleasure in testifying.

In order to make the analyses of value it was necessary to take great care in securing the samples, avoiding selected hap-hazard ones. For this purpose all assistants in the field were instructed to take their own samples. The instructions were as follows: "Secure *samples* for *analysis* from *largely-worked localities;* take fragments from not less than 50 blocks, reduce them to small pieces, thoroughly intermix them, and take two or three lbs.; * * * * make sure of *fair average.*" The above applies to coal and iron ore. Limestones, clays, etc., were sampled in the same general manner, with such minor changes as the character of the material suggested. An alternative method was sometimes used in which the samples for analysis were secured by channeling the entire coal seam from top to bottom, only the partings and rejected portions of the seam being omitted. The samples so taken were sent in canvas bags to the laboratory, marked with name of sender, locality, and such other notes as served to fully place them; as soon as received they were placed on record and marked with a proper laboratory number. The sample was prepared for analysis by grinding the whole as received, in a mortar, sifting all through a sieve of from $\frac{1}{8}$ to $\frac{1}{20}$-inch mesh, according to size of the original sample; this was then thoroughly mixed, divided, and at least a pound put through a $\frac{1}{25}$-inch seive. This

was mixed, and 100 to 200 grammes of it, after being pulverized so as to go through a 90-mesh sieve, bottled for analysis; thus *all* of each sample received was averaged carefully.

The material, as bottled, was used directly for analysis *without drying, at* 100°; this method of working was adopted as giving the actual composition of the material, as received; moisture was, of course, determined where present, and entered in the analysis.

The materials analyzed were coals, limestones, iron ores, fire-clays, pig-irons and slags. The methods pursued in these analyses were those regularly in use in the laboratory, but a brief outline will be given of each, as there are several rather important differences from those presented by Dr. Wormley, and published in the first chemical report in the volume for 1870.

Coals.—Only the "proximate" analysis was made; this was by the usual method, as follows: One gramme of the coal placed in a weighed platinum crucible was transferred to an air-bath and dried at 100° C for 1 hour; the loss of weight was water. The same crucible with its charge of coal was then heated 3½ minutes over a Bunsen burner, and then, without cooling or being uncovered, over a blast lamp 3 minutes, then cooled and weighed; the further loss was the "volatile carbonaceous matter." The coke remaining was then slowly burned by heating the uncovered crucible over a Bunsen burner until nothing but ash remained, which, being weighed and deducted from, the previously found weight of coke, left the "fixed carbon."

The results obtained by this well-known method are fairly uniform, and correspond closely with the results obtained in a large way on coking. This method differs radically from that used by Dr. Wormley, which consisted in heating the coal in a platinum boat placed in a glass or iron tube. That our present work might be compared with his, one of the samples from the old Survey was obtained from the Geological Museum of the State University, and being first re-analyzed by Dr. Wormley's method, was then examined by the present one, with the following results (the sample in all is identical):

1. Dr. Wormley's analysis.
2. Dr. Wormley's method, analysis by Lord.
3. Present method.

	1.	2.	3.
Moisture	8.70	7.20	7.20
Volatile combustible matter	28.30	28.95	33.02
Fixed carbon	58.80	59.22	55.15
Ash	4.20	4.63	4.63
Total	100.00	100.00	100.00
Sulphur	....	....	....

The sample had dried a little from keeping, but otherwise was unaltered. Dr. Wormley's method will hence show about 4 per cent. more "fixed carbon" than the present. The difference appears to be due to the fact that the heat attainable in a tube fails to expel the last traces of hydrocarbons, or else the vapors "crack" or split up into carbon and lighter gases in the tube more than in the crucible. The first supposition appears more probable from the following experiment: One gram of the same coal was treated by the present method, but weighed *before* heating with the blast lamp. It gave fixed carbon, 59.78 per cent., or nearly the same as when heated in a tube, showing that probably some of the vapors are only expelled at a very high heat.

I have discussed this at length, so as to explain the constantly lower result in fixed carbon shown by the present series of analyses. The "fixed carbon" is so entirely dependent upon the method of analysis that it is important that only results by the same method be compared. The method used was adopted as being, besides more convenient, at present, perhaps the most usual, and also representing more nearly the yield of coke in the large way.

Sulphur in Coals.

Two methods were used for the determination of sulphur. 1st. The method by fusing the coal with sodic nitrate and carbonate. Taking one gramme of the finely pulverized coal or coke, mixing intimately with 8 grammes of sodic nitrate and 8 grammes of sodic carbonate, then deflagrating carefully in a large platinum crucible, extracting the fused mass with water, evaporating to dryness with hydrochloric acid, taking up again in acidulated water, and in this solution, precipitating the sulphuric acid with baric chloride. This method was finally given

up for Escha's method with magnesia, using Dr. Drown's modification.

2nd. This method avoids the excessive wear of the platinum crucibles which the ordinary method occasions, gives results fully as accurate, and also avoids the presence of such an excess of saline compounds in the solution in which the baric sulphate is precipitated.

Before adopting it, a large number of duplicate determinations by both methods were run through with satisfactory results; in a few cases, where notable differences resulted, the Escha method gave the higher results, and considering the great liability to *loss* while deflagrating the sodic nitrate and coal mixture, the error certainly seemed explained thus.

The Escha method, as we used it, was as follows: One gramme of coal or coke was well mixed with one and a half grammes of a mixture of one-third pure, dry, carbonate of soda, and two-thirds dry, pure, ignited magnesia.

The light mixture was transferred to a platinum crucible of about 30 c. c. capacity, which was then heated very slowly and gradually over a Bunsen burner, the crucible being tilted on its side, and the flame turned so low that all generation of gas in the crucible was avoided; the mixture gradually and quietly burns white. When so burned (which takes from 45 minutes to an hour) the mixture, which does not fuse, but remains as a powder, is transferred to a beaker, water added, digested warm for a few minutes, filtered, and the residue washed. To the filtrate was added a *little* bromine water, the excess of which was expelled by heat, and the sulphuric acid precipitated with baric chloride.

In all sulphur determinations it was found impossible to obtain reagents free from sulphur. The nitrate and carbonate mixture used in the first method was made in considerable quantities at a time, mixed well, and the sulphur it contained accurately determined; this was then, in all cases, deducted from that found in the coals. The amounts thus found in "chemically pure" sodic carbonate was in some cases equivalent to $\frac{2}{10}$ to $\frac{3}{10}$ of a per cent. on the gramme of coal.

The same difficulty was encountered in preparing magnesia for the Escha method; "chemically pure" magnesia yielded sulphur so abundantly that it was discarded, and the following method adopted for obtaining better: good commercial magnesia was boiled with sodic carbonate, then washed by decantation until the liquid, acidified by hydrochloric acid, ceased to yield a precipitate with baric chloride. The magnesia

hydrate was then dried and ignited; it still contained *soda,* but was free, or nearly so, from sulphur.

The sodic carbonate and magnesic oxide mixture was, however, treated like the other mixture, and its correction in all cases determined, but it usually amounted to but a few hundredths per cent., owing to the smaller relative amount of the reagents used.

The analysis of the ashes was made in the same way as iron ore analysis; the ashes were prepared for analysis by burning about 100 grammes of the coal carefully in a platinum dish or large crucible, either over a Bunsen burner, or in the muffle of a cupel furnace.

Iron Ores.

The quantity taken for complete analysis was 5 grammes, which was treated with hydrochloric acid, evaporated to complete dryness, then treated with more acid and water; the residue insoluble in acids was fused with sodic carbonate in a platinum crucible, dissolved in water and hydrochloric acid, then evaporated *dry,* and the silica thus separated was weighed. The solution was added to that from the original treatment of the ore, and the combined solutions were diluted to 500 cubic centimeters and aliquot parts used for different determinations, iron being determined volumetrically in two portions of 50 c. c., representing $\frac{1}{2}$ gramme each.

A solution of potassium bichromate was used for titriring the iron. The iron being reduced by sodic sulphite (if the solution be partly neutralized with sodic carbonate, so as to prevent any great excess of free acid being present, the reduction is almost immediate) is strongly acidified and boiled to expel the excess of sulphurous acid. The rule in the laboratory was to boil till the odor of sulphurous acid has ceased, and then to continue boiling for five minutes longer. Duplicates by this method agree almost exactly. The bichromate method (Dr. Penny's) was employed because of the ease of preparation of the iron solution and the stability of the standard.

Phosphorus was determined in 200 c. c. of the solution (corresponding to 2 grammes of the ore). The oxide of iron and phosphoric acid being precipitated by ammonia, washed by decantation, dissolved in nitric acid, partly neutralized with ammonia, and the solution precipitated by a large excess of "ammonic molybdate solution," the precipitate was then washed with the diluted precipitant, dissolved in

ammonia; if a clear solution was not obtained, it was reprecipitated by acidifying with nitric acid and adding more molybdic acid solution. The resulting precipitate was washed again in dilute "molybdate" solution, redissolved with ammonia, the solution thus obtained being precipitated with an ammoniacal solution of magnesic chloride, care being taken to secure a *gradual* crystallization of the ammonio-magnesic phosphate by a cautious addition of the "magnesia mixture" accompanied by stirring. The other elements were determined in 100 c. c. (= 1 gramme) by first precipitating the iron, alumina and phosphorus, by boiling the almost neutral solution, with the addition of sodic acetate. The filtrate, after the separation of the manganese as dioxide by adding bromine water and heating for some hours, was used for the determination of lime and magnesia as in limestone.

The precipitate of manganese dioxide, produced by the bromine, was washed well, and if in very small amounts, as was usually the case, was ignited and weighed as manganese proto sesquioxide ($Mn_3 O_4$); if present in larger amounts, it was dissolved and converted into phosphate and weighed as such.

The precipitate of ferric oxide and alumina was redissolved in hydrochloric acid, diluted, boiled, precipitated with ammonia, and the precipitate weighed. From the weight of this the ferric oxide and phosphorus was deducted, what remained being the alumina.

Sulphur was invariably determined in a separate portion of the ore by fusing with a mixture of sodic-nitrate and carbonate, extracting with water, and after evaporation with hydrochloric acid to separate silica, filtering and precipitating with baric chloride.

Moisture was determined by drying a portion at 100° C, and weighing the loss. Combined water was determined by heating to redness in a platinum crucible, then igniting slowly for a long time, in some cases with the addition of a little nitric acid so as to convert all iron oxides to the *ferric* state, and then weighing the loss.

The phosphorus is only completely gotten into solution by fusing the residues as described; weighing the "insoluble silicious matter" directly, and not treating for phosphorus, is, in the experience of our laboratory, sure to involve loss of that element.

In case of "blackbands" and similar highly carbonaceous ores, the organic matter and the water were expelled by careful burning and

oxidation with nitric acid, and the whole loss reported as organic and volatile matter.

Limestones.

No departure from the usual method was made—the method being to dissolve one gramme of the sample in hydrochloric acid, evaporate dry, add acid and filter from the insoluble portion; the insoluble portion was then fused with a little sodic carbonate, and treated as in case of iron ores.

The solution, free from silica, was first precipitated by ammonia to separate iron and alumina, which were usually weighed together; in some cases the iron was determined also by reducing a portion of the solution and titriring.

The filtrate from the iron and alumina was precipitated hot by a solution of ammonia oxalate, allowed to settle, filtered and washed. The precipitate of calcic oxalate was either weighed as carbonate or as sulphate. The heating by which it is made into carbonate has to be very carefully managed; it was accomplished on a sort of sand bath, made by putting some clean washed sea sand into a large (60 c. c.) platinum crucible, and then heating over a regulated Bunsen burner until it was just red hot; into this large crucible could be set the small ones holding the oxalate, which was thus rapidly and safely converted to carbonate without the tedious process of heating "by hand." When a number of ignitions were to be made, this was found to be economical of time. All the weighed precipitates were duly tested for caustic lime.

Where magnesia was present in at all large quantities, the original calcic oxalate precipitate was redissolved in a little hot hydrochloric acid, diluted with water and reprecipitated with ammonia and a fresh portion of ammonia oxalate, to recover the small quantity of magnesia taken down with the first precipitate. The ammoniacal filtrate from the lime was then precipitated with excess of hydrodisodic phosphate.

Where the lime was determined as sulphate, the oxalate was treated in the crucible with slight excess of strong sulphuric acid, heated carefully till *dry,* ignited and weighed.

For all precipitates adopted to its use, the "Gooch" perforated crucible and asbestos filter was used; the following arrangement was found very convenient for the exhausting vessel: upon a sheet of heavy

plate glass, a short cylinder of glass, having both edges ground, was placed, and above this a second plate of glass, having a hole bored in it near the edge. Into this hole, lined with a collar of rubber, a funnel holding the crucible was placed, and inside the cylinder, below, was placed the beaker to catch the filtrate. Into the side of the cylinder a hole was bored, into which a rubber cork and glass tube were fitted, and to which the Bunsen suction pump was attached. A three-way stop-cock in this tube turned on suction or admitted air so as to avoid the running back of water from the pump when suddenly stopped. The apparatus can be easily constructed; the cylinder was made by cutting off the top and bottom of an acid bottle, and the plate of glass and cylinder were bored by a piece of brass tube and emery powder. The great advantage was in having the top plate movable as to position, so that the stem of the funnel could be placed against the side of the beaker and the beaker and filtrate removed; in fact, the apparatus is as convenient as an ordinary filter stand in respect to handling funnel and filtrate.

In some limestones, water was determined directly by heating in a glass tube and catching the vapor in a calcic chloride tube.

In the course of analysis, when an unusual amount of ammoniac chloride had been formed (as in the case where lime had been redissolved) the filtrate from the magnesia was evaporated nearly to dryness, and the ammonia salts decomposed by heating with nitric acid as described by Dr. J. Lawrence Smith, and the so purified liquid diluted and reprecipitated with ammonia, thus yielding, in some cases, a further trifling precipitate of magnesia (which seems to be "kept up" by a *large* excess of the *salammoniac*).

Furnace slags were analyzed by the same general methods as iron ores.

Pig-Irons.

The number of pig-iron analyses made was small; hence, but a short statement of the methods used will be given.

The carbon was determined by dissolving the iron in double chloride of copper and ammonia, filtering out the residues on to asbestos, then converting the carbon to carbon dioxide by Ullgren's chromic acid method and absorbing in potash bulbs. The potash bulbs were protected by a small chloride of calcium tube placed both before and after them; this was found necessary to insure complete freedom from

loss in weight. The constancy, in this respect, was tested by aspirating a considerable quantity of air through them, and weighing repeatedly. Sulphur was determined by dissolving in hydrochloric acid, and passing the resultant gas through U tubes, containing a solution of potassic permanganate (Drown's method). The solution in the flask was then filtered, the residues fused with a little nitrate and carbonate of soda, dissolved, evaporated with acid and added to the permanganate solution After reducing, the clear solution was precipitated by baric chloride. Five grammes of the iron was used for each determination. The iron was in most cases prepared for analysis by drilling with a dry, clean drill, and mixing the chips from several parts of the sample. Silicon was determined by Drown's nitric and sulphuric acid method. So much discussion has taken place as to the determination of phosphorus, and, as quite a number of results are given in the chapter on iron which are taken from private notes of former work and will not be repeated in the tables of analyses added here which only include those made for the survey and which results were obtained by the same method, it will be given in full.

Two grammes of the iron were placed in a beaker, with 200 c. c. of water and 4 or 5 grammes of chlorate of potash, the whole heated until the salt was dissolved, and hydrochloric acid was then added gradually until the iron was dissolved. By taking time, the solution takes place without any notable evolution of gas.

The solution so obtained was evaporated, dried, and taken up with hydrochloric acid. The residue from filtration was fused with sodic nitrate and carbonate, and the fused mass treated as in iron ores, the solutions being combined. The liquid then was treated as in the case of iron ores. The fusion of the residue seems to be absolutely necessary to obtain all the phosphorus, as from $\frac{1}{10}$ to $\frac{1}{20}$ of the whole present has been shown by numerous trials to be retained there after the first solution where silica is present to any considerable extent. The same results are obtained if nitric acid is used as the original solvent.

The above method is essentially the one used for years at the School of Mines in New York, and published by Mr. Cairns in his book on analysis; it is, according to my experience, the most satisfactory, though not the shortest. It seems that *no general method* is satisfactory for phosphorus, that omits the examination of *every* product for phosphoric acid; such a method as will give uniform results with materials similar

in general character, applied to something widely different is sure to lead to false results, unless each residue, precipitate and solution is examined, any phosphorus contained extracted and added to the total. Having obtained *all* the phosphorus in a clear nitric acid solution, it can be determined by precipitation with molybdic acid, and accurately weighed as magnesic pyrophosphate. The only uniform method, applicable to any iron, will be one that is *accurate* in all cases (and this must be proved for each case), and does not depend upon a supposed uniform loss, or balance of errors. Manganese was precipitated in the obtained filtrate, after separating the iron from the solution of pig-iron by sodic acetate, by bromine, as described under analysis of iron ores.

Fire-Clays.

The general method was as follows: One gramme of the clay was fused with 5 or 6 times its weight of sodic carbonate, and the fused mass treated as in case of iron ores. The silica thus separated was weighed. The solution was then treated as in case of a limestone, taking care to insure a complete separation of the alumina by long boiling till all the free ammonia was expelled.

The iron was determined volumetrically in a separate portion, fusing and dissolving as before. The titration was made with a dilute potassic permanganate solution, carefully standardized.

The alkalies were determined by the J. Lawrence Smith method, using chloride of ammonia and carbonate of lime to decompose the clay. The alkalies being obtained in solution as chlorides, were evaporated to dryness after separating all lime and other bases, ignited to expel ammonia salts, then dissolved, and the solution filtered, and then again evaporated in a platinum dish, and the dry salt weighed. The potassa was then separated with platinic chloride, and weighed as the double chloride of potash and platinum. The "indirect method" of determining potassa and soda, while it did not "work," owing to the small amounts of soda present (this element only appearing in most cases in traces), led to the interesting discovery of *lithia* as a nearly constant element in the Ohio fire-clays. Too much chlorine having been found by volumetric determination in the dried salts obtained as above to supply the potassa and soda, the cause of the discrepancy was investigated, and finally *lithia* was discovered with the spectroscope in quite (spectroscopically) considerable quantities. To put the question beyond

doubt, blank analyses were made using nearly similar amounts of all the chemicals, but omitting the clay. No lithia was found in such blanks. Hence, the interesting fact is certainly proved that Ohio fire-clays contain *lithia*.

This is, I believe, the first recorded instance of the presence of this element in clays of the United States. It was found almost invariably. It has not been possible as yet to ascertain the mineral combination in which it exists, but presumably it exists as lepidolite or lithia mica. Considering the enormous deposits of clays, which the survey samples represent, this is another instance of the wide distribution of the so-called rare elements, which, when carefully looked for, will probably be found, as Prof. Crookes has lately found zirconia, in most unsuspected places.

Another element found in the Ohio clays, but hitherto, I believe, unreported in the survey, is titanium. It was first noticed in the clays from Logan during some analyses made in the Mining Laboratory of the University, some 3 or 4 years ago. The following method of determining it was devised for the survey work, and found quite satisfactory as a means of dissolving and separating this somewhat refractory element:

One gramme of the clay was fused with sodic carbonate, then digested with water, and filtered. A large part of the silica is separated thus as sodic silicate. The residues, containing some silica, iron, alumina, and the titanic acid, is then dissolved in hydrochloric acid. It gives a clear solution, to which sulphuric is added, and the mixture evaporated on the water-bath until the hydrochloric acid is expelled; this evaporation precipitates most of the silica, but owing to the strong sulphuric acid present, none of the titanic a id ($Ti\ O_2$). The solution was now cooled, diluted with cold water, and filtered into a large beaker or flask, nearly neutralized with sodic carbonate, and an excess of sulphurous acid added to reduce all iron. The solution was now boiled slowly for some hours, the sulphurous acid being replaced from time to time as it was expelled by boiling. The titanic acid is rapidly precipitated as a flaky, easily-filtered, precipitate, which is filtered off, dried, and then fused with a little bisulphate of potassa, extracted with cold water, and the solution treated as before. The reprecipitated titanic acid is *pure*, and, after weighing, may be tested by the blow-pipe for iron as a precaution against error.

A most important point in the clay analysis was the determination of the combined as distinguished from the "sand" silica. The method was essentially that employed by Prof. Cook in the New Jersey survey. We used it as follows:

One gramme of the clay, very finely powdered, was digested from 12 to 24 hours in a flask on a sand-bath with 10 to 15 cubic centimeters of strong sulphuric acid; the temperature kept near the boiling point of the acid till the clay was completely decomposed. The mixture, well cooled, was diluted with cold water and filtered. The silica so obtained was weighed, then ground fine in an agate mortar; to it, 50 or 60 c. c. of a 15 per cent. solution of potassa was added, and boiled five minutes, filtered and washed. The residue was sand and undecomposed silicates, which, deducted from the weight of the total found above, gave the weight of the "combined silica"; this again deducted from the total silica found in course of the regular analysis, gave the silica present as sand. The results obtained thus were quite uniform, and corresponded well with the observed characters of the clays.

The sulphuric acid solution of the clays so treated, after reduction with zinc, served admirably for the titration of the iron they contained. Such is an outline of the analytical methods used in making the present series of analyses. For convenience of reference, the tabulated results of the survey work are given below. In the coal analyses, the "fuel ratio" or quotient of fixed carbon divided by the volatile combustible matter is given, as this eliminates the influence of the ash, and shows the dryness, or otherwise, of the coal.

The sulphur of the coal is not included in the totals of the analyses; as it is not possible to tell just how much goes with volatile matter, and how much with fixed carbon, so it is always given separately. There are a number of analyses in the present volume not included in these tables. Such are, in most cases, taken from private analyses made in the laboratory, which I was permitted to use, but which are not part of the chemical work of the survey.

ANALYSES OF COALS.

Record numbers.		Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.
	Athens County.						
123	Carbondale coal, M. & C. R. R.	5.05	38.55	49.62	6.78	2.63	1.28
124	Sample from mine of C. L. Poston & Co., Nelsonville, Ohio	5.73	36.76	51.99	5.52	1.42	1.41
125	From mine of L. Steenrod, S. E. of Nelsonville	5.38	37.58	51.21	5.83	1.94	1.36
126	Little Brier Hill coal, near Bessemer, top bench of Big Vein	5.12	33.88	51.23	9.77	1.63	1.51
127	Johnson Bros. & Patterson, across Hocking R., from Nelsonville	5.44	37.53	51.51	5.52	1.23	1.37
128	Little Brier Hill coal, Middle Bench of Big Vein, near Bessemer	5.92	37.59	53.43	3.06	1.41	1.42
132	Little Brier Hill coal, bottom bench of "Big Vein", near Bessemer	5.88	37.77	51.99	4.36	1.94	1.37
133	Little Brier Hill coal (not mined), 2 ft. thick, 2′–4′ above top of Big Vein	3.03	43.75	40.74	12.48	4.86	.93
135	Bayley's Run coal, Johnson Bank, Trimble township, Mud Fork	4.40	41.44	50.05	4.11	3.37	1.20
136	Nelsonville Coal & Coke Co., Buchtel, Ohio	5.10	36.97	49.68	8.25	2.41	1.34
138	Akron Iron Company's coal, Buchtel, Ohio	5.68	35.79	54.13	4.40	.58	1.51
139	Lower Bench, Pittsburgh coal, Bern tp., S. W. ¼ Section 13, W. W. Wickham's bank	3.85	41.12	47.99	7.04	4.07	1.16
	Belmont County.						
214	Wheeling Creek Coal Co., Bridgeport (Mine No. 2), Pittsburgh seam	1.87	41.70	50.16	6.27	3.67	1.20
233	Meigs Creek coal, Upper Barnesville coal, Wm. Davis & Bro	2.09	40.05	47.77	10.06	2 98	1.19
235	Pittsburgh Coal Works, Bellaire, O.	1.52	41.70	48.69	8.09	4.95	1.16
236	Roof coal, No. 8, Hetherington Mine, Bellaire	1.93	40.54	45.80	11.73	6.33	1.12
237	Pittsburgh coal, Mine of W. G. Barnard, Bellaire	1.87	40.76	50.10	7.27	4.13	1.22
238	Coal from shaft of Captina Coal Co., on B. Z. & C. R'y, Washington township	1.55	42.47	47.70	8.28	5.14	1.12
246	Pittsburgh Coal, Rock Hill Coal Co., near Flushing	2.76	40.85	48.92	7.47	3.24	1.19
247	Meigs Creek Coal, Flushing Coal Co.'s Mine, Flushing, Ohio	3.18	38.31	50.10	8.41	1.78	1.30
248	Pittsburgh Coal, Rainey Bank Coal Co., just above Martin's Ferry	2.05	40.41	50.57	7.99	4.20	1.24
249	Pittsburgh Coal, Kidd Bros. mine, Barton P. O.	1.98	39.64	50.58	7.80	3.97	1.27

ANALYSES OF COALS—Continued.

Record numbers.		Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel r tio.
	Belmont County—Continued.						
250	Pittsburgh & Wheeling Coal Co., Pittsburgh Mine, at Maynard Station, C., L. & W. R. R., Belmont Co	2.46	39.36	50.91	7.27	2.89	1.29
258	Pittsburgh Coal, Wheeling Creek Mines, 2 miles west of Bridgeport	1.74	41.39	48.90	7.97	4.12	1 18
261	Bellaire coal, Jacob Heatherington's mine, Pittsburgh seam, Bellaire, O	1.53	42.29	47.57	8.61	4.47	1.12
	Carroll County.						
58	New York & Ohio Coal Co., Sherrodsville, Orange township	4.20	39.32	52.58	3.90	1.92	1.27
60	New York & Ohio Coal Co., Mines of Samuel Allen & Son, Dell Roy	4.20	37.01	51.64	7.15	3.09	1.39
105	Empire No. 2, whole seam, Dell Roy	3.81	36.27	55.02	4 90	1.57	1.51
106	Empire No. 2, from cars, Dell Roy	3.69	38.13	52.75	5.43	2.87	1.38
107	Empire No. 2, bottom 15″, selected as best coal, Dell Roy	3.95	35.12	52.67	8 26	1.62	1.62
	Columbiana County.						
56	Anderson Bank, Manufacturers' Coal Co., Strip Vein, Salineville	3.26	37.49	53.74	5.51	1.22	1.43
57	Ohio & Penn. Coal Co., Hussey Bank, Big Vein, Salineville	2.32	39.08	52.78	5.82	2.88	1.35
208	State Line Mine, Upper Freeport seam, East Palestine	2.10	39.37	53.46	5.07	2.87	1.35
218	Leetonia Bank, average	3.60	37.86	56.14	2.40	.82	1.48
220	Washingtonville Bank, average	4.37	35.50	57.91	2.22	.69	1.63
	Coshocton County.						
25	Bedford Cannel coal, Mine of Jos. Sharpless, Warsaw, Bedford tp.	2.35	47.05	37.00	1.36	2.33	.78
26	Coshocton coal, Home mines, Coshocton, O	5.07	42.07	48.40	4.46	2.91	1.15
27	Coshocton coal, Union mines, near Coshocton, O	4.41	43.98	46.38	5.23	3.99	1.05
52	David Davis's coal, Virginia township	4.61	44.73	47.83	2.83	2.28	1.06

	Guernsey County.						
108	Coal No. 5, Lower Kittanning, from trial pit, at Warden's Salt Works, Wills Creek, below Cambridge	3.05	39.27	50.12	7.56	1.65	1.27
110	Cambridge coal, Buffalo Mine, average, Hartford	3.97	34.78	56.32	4.93	.79	1.61
111	Cambridge coal, average (Nicholson's), Ohio Coal Company's mine.	3.84	37.90	53.83	4.43	1.36	1.42
112	Cambridge coal, Akron Coal Campany's mine; sampled from the seam, Byesville	3.30	35.85	54.13	6.72	1.68	1.50
113	Cambridge coal, Wm. Norris's mine, average of product, Leatherwood Creek, Cambridge	2.91	37.84	51.07	8.18	3.13	1.34
199	Cambridge Coal, Guernsey Coal Co	5.32	37.46	53.29	3.93	1.38	1.42
	Hocking County.						
137	Hocking coal, M. A. Suydam	5.26	36.12	54.59	4.03	.64	1.51
129	Bottom bench of Big Vein, W. B. Brooks & Son., Snake Hollow	7.24	34.78	56.09	1.89	.54	1.61
130	Middle bench of Big Vein, W. B. Brooks & Son	6.77	37.31	54 18	1.74	.51	1.44
131	Top bench of Big Vein, W. B. Brooks & Son	5.83	37.12	52.25	4.80	.50	1.41–
243	T. Longstreth's coal, Monday Creek (selected from coal shed)	8.48	36.97	52.42	2.13	.47	1.41
	Holmes County.						
4	Bowen Brothers' coal, average, Hardy township	5.41	42.39	45.38	6.82	4.72	1.07
5	Bowen Brothers' coal, picked sample, Hardy township	7.44	41.42	48 61	2.53	2.28	1.17
11	Bank of Elias Mast, Hardy township	5.11	41.01	47.15	6.73	2.99	1.14
28	Lower Bench, S. R. Williams, Monroe township	6.57	41.44	47.49	4.5	1.62	1.14
29	Upper Bench, S. R. Williams, Monroe township, mine one mile N. W. of Centerville	5.62	41.65	48 25	4.48	2.72	1.15
76	Upper Bench, Cary & Urmson, Killbuck township	4.37	43.82	44.68	7.13	5.08	1.01
77	Lower Bench, Apple Creek Mine, Baker's	6.65	37.26	50 18	5.91	1.62	1.34
78	John Amsbaugh, Salt Creek township	3.80	43.45	42.80	9.95	4.95	.98
79	Lower Bench, blacksmith coal, A. Scar, Walnut Creek township	5.63	39.59	49.88	4.90	2.54	1.25
80	Upper Bench, A. Scar, Walnut Creek township	5.55	41 41	49.87	3.17	2.35	1.20
81	Valentine Hershberger's coal, Farmerstown, German township	4.51	44.86	44.55	6.08	4.68	.99
82	Old Holmes Co. Bank, Cary & Urmson, 4 miles south of Millersburgh, Killbuck township	5.50	42.03	44.59	7.88	3.86	1.06
83	Dr. P. P. Pomerine's coal, Berlin, Berlin township	4.41	44.05	45.17	6.37	4.74	1.02
84	Andrew Schrock's coal, Walnut Creek township	4.49	42.50	47.27	5.74	3.41	1.11
85	John Purdy's coal, Mechanic township	4.10	42.47	42.24	11.19	5.08	.99

ANALYSES OF COALS—Continued.

Record numbers.		Moisture.	Volatile combustible matter.	Fixed carbon.	Ash	Sulphur.	Fuel ratio.
	Jackson County.						
74	Hill coal, H. L. Chapman, Section 9, Lick township	8.89	34.03	52.60	4.48	.96	1.54
90	Enoch Canter coal, J. Gilliland, Jackson township	7.04	37.89	44.09	10.98	1.19	1.16
109	Kyle, Shotts & Co., sampled from cars at mine, Jackson, Ohio	8.57	32.70	55.43	3.30	.47	1.69
150	Jackson Hill Vein of coal, Southern Ohio Coal & Iron Co., Coalton	7.46	36.40	54,97	1.17	.68	1.51
171	Cannel coal, 77 feet below Ferriferous limestone, Coal Run	2.32	44.52	41.13	12.03	.84	.92
172	Wellston coal, from loaded cars at Wellston Coal and Iron Co.'s Shaft, No. 2	8.57	36.40	51.39	3.64	.61	1.41
	Jefferson County.						
61	Sample of coal, from mine of Wm. S. Finley, near Brown's Station	1.80	40.60	52.54	5.06	2.62	1.29
62	Steubenville Coal & Mining Co., Steubenville	2 06	39.06	53.96	4.92	1.79	1.38
63	Hammondsville Strip Vein coal, W. H. Wallace & Son, Hammondsville	1.89	37.17	53.67	7.27	.72	1.44
64	Yellow Creek Diamond Vein Coal, Diamond Coal Mine, S. W. & W. G. McCullough, Linton	1.67	39 28	52.16	6.89	3.43	1.32
213	Kelley Coal, Nebo, Springfield township	2.15	39.45	50.10	8.30	2.84	1.26
263	Jefferson Iron Works, Coal Shaft No. 2, Steubenville	1.99	38.28	57.44	2.29	.85	1.5
262	Brilliant Coal Shaft, Steubenville seam, Brilliant, Ohio	1.85	37.82	55.62	4.71	1.32	1.47
260	Brilliant Coal Mines, hill coal, Pittsburgh seam, average from cars, Brilliant, Ohio	1.83	40.06	51.09	7.02	3.31	1.27
	Medina County.						
86	Diamond Coal Co., Coal No. 1, Humphreys & Coleman, Wadsworth, Ohio	6.25	36.75	53.12	3.88	1.44	1.44
88	Silver Creek Mining & R. R. Co., Shaft No. 2, Wadsworth	5.38	38.22	49.77	6.63	1.91	1.30
87	Excelsior Coal Co., Coal No. 1, Ries & Co., Wadsworth, O	6.10	37.01	51.00	5.89	1.69	1.37

	Meigs County.						
228	Pomeroy Seam, Middleport, Salisbury township	4.72	38.95	46.21	10.12	2.03	1.18
229	Pomeroy Coal Co., Peacock Mine, Pomeroy, Ohio	4.75	39.15	50.35	5.75	.77	1.28
331	Blacksmiths' coal, from lower part of seam, Hooper's Bank, Rutland township	3.23	46.21	45 40	5.16	4.67	1.22
232	Pomeroy Seam, Minersville	3.50	40.17	47.89	8.14	1.96	1.19
234	Hooper's coal, exclusive of the blacksmith coal, Rutland township	3.94	44.54	43.80	7.72	3.78	.98
	Morgan County.						
170	Cumberland coal, Marsh Bros., S. Meigs Creek Valley	1.97	43.69	42.87	11.47	7.22	.98
173	Valentine Sewall's coal, in N. W. ¼ Section 1, Bloom township, called Cumberland coal, in Vol. I., O. G. Report	3.15	41.50	38.74	16.61	5.73	93
174	Cumberland coal, bank of R. W. Combs, S. E. ¼, S. W. ¼ Section 9, Centre township	2.35	41.67	43.38	12.60	5.69	1.41
175	Cumberland coal, from farm of John Wainwright, in E. ½, S. W. ¼ Section 28, Centre township	3.00	40.83	45.75	10.42	5.35	1.12
176	Cumberland coal, Wm. Barkhurst's land, S. W. ¼ Section 26, Bloom township	3.68	40.44	43.41	12.47	5.74	1.07
177	Davis Bank, N. E. ¼ Section 8, Malta township	4.62	39.88	44.31	11.19	4.18	1.11
178	Cumberland coal, R. Whipple's bank, S. W. ¼ Section 36, Morgan township	3.75	40.55	44.02	11.68	5.69	1.08
179	Cumberland coal, Abram Farris's land, N. W. ¼ Section 35, Morgan township	4.20	38.65	43.83	13.32	5.37	1.13
180	Coal from J. Parson's bank, N. W. ¼ Section 14, Union township	5.04	41.36	45.64	7.96	5.08	1.10
181	Bone coal or tough streak, from centre of Cumberland coal, as found on Jas. Reed's land, S. W. ¼ Section 31, Bristol township	4.62	33.33	42.41	19.64	2.64	1.27
182	Probably Cumberland coal, bank of David Downing, N. W. ¼ Section 6, Bristol township	3.23	42.98	44.76	9.03	5.66	1.04
183	Cumberland coal, land of Charles Walker, S. E. ¼ Section 1, Meigsville township	2.57	41.50	46.65	9.28	4.30	1.12
184	Probably Cumberland coal, J. Knight's land, N. W. ¼ of N. E. ¼ Section 2, Bristol township	2.66	43.26	44.89	9.19	4.79	1.03
185	Probably Cumberland coal, bank of A. P. Wilson, in S. E. ¼ N. E. ¼ Section 33, Bristol township	3.09	40.44	46.51	9.96	5.50	1.15
186	Cumberland coal, from land of J. W. Barkhurst, in S. E. ¼ Section 13, Meigsville township	2.98	37.17	43.55	16.30	4.50	1.17
187	Probably Cumberland coal, Bank of Webb Lawrence, S. W. ¼ of Section 20, Bristol township	3.15	41.45	46.20	9.20	4.80	1.11

ANALYSES OF COALS—Continued.

Record numbers.		Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.
	Morgan County—Continued.						
190	Pittsburgh Coal, John Steffy's bank, Section 29, Homer township...	5.39	41.18	46.32	7.11	4.16	1.12
191	Cumberland coal, land of E. Sherwood, S. E. ¼ Section 19, Morgan township	3.85	36.72	42.43	17.00	5.23	1.15
192	Probably Cumberland coal, bank of Jas. Noyce, lot 75, Windsor township	3.93	40.84	46.49	8.74	4.01	1.13
193	Cumberland coal (?), J. Male's bank, in Washington Co., just over the line from S. E. ¼ Section 2, Marion township	3.94	39.45	44.12	12.49	4.97	1.11
194	Pittsburgh Coal, Mansfield Petroleum Co.'s Bank, N. W. ¼ Sect. 32, Homer township	4.55	39.99	45.46	10.00	4.89	1.13
195	Pittsburgh Coal, Lower bench, bank of Wm. Hogshead, Section 6, Homer township	5.30	40.18	48.50	6.02	2.87	1.20
	Muskingum County.						
72	Coal No. 6, Horton, Matthew & Taylor's Mine, Washington tp	4.82	40.91	48.67	5 60	3.57	1.18
73	Coal No. 5, bank of Ebenezer Harper, 4 ft. 8 in. seam, in Mill Run, one mile from Blast Furnace, Zanesville	4.93	39.72	49.96	5.39	3.45	1.25
188	Coal from the Patriot Vein, on Jacob Osborn's land, Section 7, Rich Hill township	3.40	42.25	46.33	8.02	2.44	1.09
189	Meigs Creek coal, John Smith's bank, Rixville, Rich Hill tp	4.04	39.59	44 58	11.79	3.81	1.12
	Noble County.						
196	Meigs Creek coal, bank of H. C. Hunter, Section 4, Brookville tp...	3.27	40.23	44.72	11.78	5.90	1.11
197	Meigs Creek coal, Jordan's farm, in S. E. ¼ S. W. ¼ Section 10, Brookfield township	3.11	40.05	45 20	11.64	4.84	1.12
198	Meigs Creek coal, bank of George McEndree, in Section 4, Brookfield township	3.84	40.61	46.32	9.23	5.18	1.14
240	Cumberland coal, land of Wm. Lincicome, N. E. ¼ S. E. ¼ Section 32, Enoch township	2.18	41.75	45.92	10.15	4.02	1.09
241	From land of Dan. Fowler, N. E. ¼ S. W. ¼ Section 29, Manchester tp.	2.42	42.35	46.20	9.03	4.64	1.09
242	Cumberland coal, Wm. Craig's land, S. E. ¼ N. E. ¼ Section 13, Marion township	1.86	39.63	45.92	12.59	6.10	1.15

	Perry County.						
45	Coal No. 6, Mine of S. & C. Jones, Sections 29 and 32, Harrison tp..	5.95	41.87	48 21	3.97	1.65	1.15
46	Coal No. 5, Adam Acker's mine, Section 19, Clayton tp	6.04	42.66	45 55	5.75	1.92	1.06
47	Mine No. 12, Ohio Central Coal Co., Upper Freeport coal, near Corning	7.50	38.38	49.57	4.55	1.10	1.29
48	Mine No. 19, Ohio Central Coal Co., Buckingham	6.50	38.85	48.87	5.78	.82	1.25
49	So-called *bone coal*, Mines of O. C. Co., Corning, etc., 10 to 12 in., in upper part of Vein, condemned and separated	6 93	35.14	47.63	10.30	.42	1.35
115	Top coal, 2 ft. now rejected, J. & F. Sheerhan's mine, Ferrara, O...	4.52	36.43	37.39	21.66	4.76	1.02
116	J. & F. Sheerhan, Ferrara, Ohio, whole seam	5.21	40.59	46.85	7.35	3.95	1.15
117	Bone coal, Ohio Central Coal Co.'s Mine, No. 13	5.38	31.46	42 25	20.91	.48	1.34
118	Top coal, Mine No. 13, Ohio Central Coal Co., 2,500 to 3,000 tons to the acre lost	5.75	31.03	40.48	22.74	.44	1.30
120	Straitsville Central Coal Co., sampled from whole seam as used for market	6.66	36.07	50.92	6.35	1.01	1.41
121	J. S. Doe & Co.'s Mine, sampled from small cars, New Straitsville, O.	6.60	34.72	52.56	6.12	64	1.51
122	J. S. Doe & Co., average of whole seam, New Straitsville, Ohio	7.09	36.61	52.00	4.30	1.19	1.42
134	Upson Mine, seam, 9 ft. 4 in., all but 9″ taken, whole seam sampled, Shawnee, Ohio	6.09	35.61	51.44	6.86	84	1.44
265	Rock Run Mine, near Straitsville, C. & H. C. & I. Co	6.15	38.53	48.95	6.37	.72	1.27
266	Bottom Bench, Rock Run Mine, C. & H. C. & I. Co	6.35	38.49	50.81	4.35	.46	1.32
267	Coal from above cannel streak, Shawnee Valley Coal Co.'s Mine, Shawnee	5.57	39.55	48.09	6.79	1.24	1.21
268	Coal from above cannel streak, Rock Run Mine	6.33	38.51	46.84	8.32	.44	1.21
269	Ohio Central Coal Co., Mine No. 5	5.29	38.32	50.77	5.62	.89	1.32
270	Lower Kittanning coal, Redfield mines	5.00	41.73	43.32	9 95	4.70	1.03
271	Ohio Central Coal Co., Mine No. 13, sampled from seam	6.11	37.99	50.59	5.31	.55	1.33
272	" " " 3, sampled from bank cars	5.70	37.80	49.22	7.28	.72	1.30
273	" " " 13, "soft bone," rejected	5.88	34.31	49.15	10.66	.60	1.43
274	" " Splint coal, Mine No. 13	2.78	45.46	39.92	11.84	.53	.87
275	" " Cannel, Mine No. 13, rejected	4.48	37.80	47.77	9.95	.52	1.26
	Portage County.						
201	Block coal seam, Palmyra Coal Co., Diamond, Ohio	4.86	36 66	56.89	1.59	.67	1.55
202	Block coal seam, Scott's Coal Co., Diamond, Ohio	4.34	37.79	54.96	2.91	.76	1.45
205	Palmyra coal, Scott's bank, second sample, cannel, except a foot at bottom	1.99	40.51	37.49	20.01	2.04	.92

ANALYSES OF COALS—Continued.

Record numbers		Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.
	Portage County—Continued.						
206	Palmyra coal, third sample, Scott's bank; No. 3 lies on block coal..	2.57	41.87	42.54	13.02	.92	1.01
207	Palmyra coal, Scott's Bank, sample represents 8″ top of seam in south entry; rejected, or but poor market found	3.79	38.01	44.52	13.68	1.09	1.17
	Stark County.						
59	Osnaburgh Coal Co., Vein No. 6, Osnaburgh	4.07	41.13	49.50	5.30	2.67	1.23
92	Coal No. 6, of Newberry, Tuscarawas Valley series, Harry Peacock Mining Co., Pike township	4.44	37.38	49.07	9.11	4.69	1.31
93	Coal No. 4, of Newberry, Evansdale Mine, Pike township..............	2.85	39.00	46.69	11.46	3.14	1.19
94	Coal No. 5, of Newberry, Tuscarawas Valley series, Willow Spring Mines, Pike township (Ridgway Burton Co.)	4.46	42.42	48.84	4 28	2.56	1.15
98	From Willow Bank, No. 5, Section 31, Jackson township	4.80	37.51	53.22	4.17	.73	1.40
99	Hard coal, Camp Creek Mine, Tuscarawas, Sugar Creek townships...	3.11	42.04	40.15	14.70	1.06	.92
100	Sippo Mine, Tuscarawas township	5.09	37.28	53.30	4.33	1.03	1.43
101	Lawrence Mine, Ridgway Burton Co., Lawrence township	5.90	35.25	57.23	1.62	.76	1.62
102	Coal from Elm Run Mine, at Justus, Sugar Creek township...........	5.65	36.08	55.70	2.57	.91	1.54
103	Coal No. 5, W. Baum's bank, Sandy township..........	3.20	41.79	51.59	3.42	1.93	1.23
200	Coal No. 4, Bottom Bench, 2′ 2″ thick, Greentown Coal Co., Greentown	3.71	40.53	42.97	12.79	5.74	1.55
203	Middle Kittanning seam, Coal No. 6, Chestnut Grove Mine, near North Industry, coal highly esteemed, Richard's Coal Co., Canton, Ohio	4.82	40.68	49.78	4.72	2.04	1.22
204	No. 4 of Newberry, top bench, 3′ thick, coal seam, 6′ thick, counted fair steam coal, Greentown Coal Co., Greentown, Ohio	3.71	42.50	48.85	4.94	3.73	1.14
	Summit County.						
67	Middlebury Shaft Mine, operated by Payne, Newton and Co.. Cleveland, Ohio, Springfield township......................................	4.72	38.10	52.78	4.40	.88	1.38
68	Mine operated by Philip Thomas, Southerly bank, Talmadge township	5.33	37.92	51.40	5.35	1.85	1.35

	Summit County—Continued.						
69	Burnet Mine, operated by Brewster Coal Co., of Akron, Norton township	5.62	38.28	49.74	6.36	1.04	1.30
70	Lakeview Mine, operated by Todd, Stambaugh & Co., of Youngstown, Coventry township	5.15	40 67	52.00	2.18	.80	1.27
71	Dennison Coal Co.'s Mine, Norton township	5.03	40.21	48.35	6.41	3.07	1.20
	Trumbull County.						
6	Block Coal, Lower Vein, No. 1 Bank, Morris, Sampson & Co., Liberty township	4.69	35.82	52.62	6.87	1.01	1.46
7	Block coal, Lower Vein, No. 2 Bank, Church Hill Coal Co., Liberty township	5.91	35.01	55.70	3.38	.76	1.59
8	Cannel coal, which sometimes comes near the middle of the block coal, Liberty township	2.42	49 29	38.00	10.29	.84	.77
9	Lower Vein block coal, Chew Bank, Brookfield township	4.38	36.16	49.80	9.66	3.07	1.37
10	Lower Vein block coal, Otis Coal Co., Cleveland Shaft, Brookfield tp.	4.60	38.36	50.42	6.62	2.02	1.31
209	Block coal, California Coal Works, Todd and Stambaugh, Hubbard township	5.76	36.72	54.91	2.16	.69	1.49
244	Brier Hill coal, from Cabinet, O. S. University	5.35	36.85	55.98	1.82	.74	1.51
	Tuscarawas County.						
50	Tuscarawas Coal & Iron Co., Vein No. 5, or Lower Vein of Big Sandy Creek Valley, Tunnel Hill Mine, Sandy township	3.35	42.14	43.73	10.78	4.77	1.03
51	Mineral Point coal, Vein No. 5, C. E. Holden's mine, Mineral Point, Sandy township	4.26	41.61	48.03	6.10	2.28	1.15
53	Top coal, Post Boy Boring, Norris's farm	2.80	31.39	43.95	21 86	.76	1.40
54	Middle coal	3.11	33.42	40.44	23.03	.92	1.21
55	Bottom coal	3.04	35.06	44.56	17.34	.70	1.27
65	Pike Run coal, Vein No. 6	2.98	43.82	45.82	7.38	3 24	1.04
66	Pike Run coal, Brook Hill Mine, No. 1, Vein No. 6	2.69	44.74	46.95	5.62	3.09	1.04
104	Coal No. 6, Washington Lebengut, Auburn township	3.66	43.97	46.78	5.59	3.79	1.06
230	Tionesta coal, only sample from Northern Ohio, near Bolivar, Lawrence township	2.94	41.40	42.94	12.72	3.30	1.03

ANALYSES OF COALS—Continued.

Record numbers.		Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.
	Wayne County.						
30	Mine of A. Rumsbaugh, Franklin township	4.68	44.04	44.01	7.27	3.34	.99
75	Baker's Apple Creek Mine, upper benches	5.48	35.28	48.84	10.40	1.50	1.35
95	Fox Lake Mine, whole vein	5.92	37.72	53.74	2.62	.68	1.42
96	Fox Lake Mine, lower part of vein	5.87	36.96	55.50	1.67	.86	1.50
97	New Chippewa Mine, Chippewa township, whole seam	5.43	38.42	51.20	4.95	1.79	1.33
	Miscellaneous.						
251	Cadiz Coal Mine of J. & A. Porter, Cadiz, Harrison Co., Ohio	2.90	39.85	49.25	8.00	3.74	1.23
252	Cadiz Coal No. 8, farm of Nancy Rutan, one mile east of Cadiz, Harrison Co., Ohio	2.92	41.00	49.57	6.51	3.79	1.20
253	Blue Rock coal, selected sample, Muskingum Co	3.50	46.44	45.87	4.19	3.84	.98
254	1st Pool, Pittsburgh coal	1.43	36 83	57.25	4.49	.95	1.55
255	2nd " "	1.40	39.54	55.31	3.75	1.08	1.39
256	3rd " "	1.39	36.18	57.36	5.07	.79	1.58
257	4th " "	1.23	34.65	56.22	7.90	1.28	1.62
264	New Castle coal, New Castle, Lawrence Co., Ohio	5.19	41.86	47.69	5.26	1.40	1.13
276	Waterloo coal, Chas. Neal's, Walnut township, Gallia Co	6.44	37.56	49.42	6.58	1.16	1.31
277	Waterloo coal, Thos. Cooper's, Waterloo, Lawrence Co.	6.98	36 65	50.14	6.23	0.57	1.36
278	Waterloo coal, Russell Brothers, Aid township, Lawrence Co.	7.13	35.52	49.64	7.71	0.56	1.39
279	Washington Furnace coal, Jackson Co	6 69	38.58	50.61	4.12	0.75	1.31
280	Flint Ridge Cannel, selected block	3.47	43 85	43.72	8.96	0.76	.99
281	Flint Ridge Cannel, average of seam	3.16	43.08	42.62	11.14	0.78	.98

ANALYSES OF LIMESTONES.

Record numbers.		Silica.	Alumina.	Iron sesquioxide.	Calcium carbonate.	Magnesium carbonate.	Water combined.	Moisture.	Totals.
3	"Buff" or Maxville, D. Hendricks, Monday Creek tp., Perry Co	3.76	(7.16)		57.86	30.78	....	.10	99.66
12	Ferriferous limestone, Lowell limestone, of Newberry, Moore farm, Section 49, Poland township, Mahoning Co., O.								
19	H. Campbell & Son, Ironton, O	1.67	(1.36)		95.40	1.38	....	....	....
20	White limestone, of Newberry, quarry of S. Stock, New Lisbon, Columbiana county	9.01	(3.38)		85.55	2.82	....	....	....
22	First limestone, below white limestone, top of stratum, New Lisbon, Columbiana county........	12.63	5.04	2.43	75.51	3.86	.49	.21	100.17
23	Middle stratum, locality same as No. 22	33.93	14.30	4.29	35.56	6.09	4 34	.86	99.37
24	Lower stratum, locality same as No. 22........	36.69	15.17	4.82	27.22	7.83	6.92	.68	99.33
42	Lowellville limestone, Lowellville	3.24	(2.26)		93.24	2.19	....	....	....
91	Ferriferous limestone, Holmes Co	2.90	(2.71)		92.02	1 85	....	....	99.55
114	Maxville limestone, ground for fertilizer, Reading tp., Perry Co., O.....	40 93	....	Iron. 22.60	4.29	4.62	....	....	....

ANALYSES OF COKES.

Rec. Nos.		Ash.	Sulphur.	Rec. Nos.		Ash.	Sulphur.
215	Coke, from slack of Big Vein, Salineville, Columbiana county, *hard*........	17.47	3 66	245	Made from slack of Coal No. 8; slack is taken from tipple, and used without washing, Rock Hill Coal, Flushing, Belmont Co........	17.74	3.57
216	Coke, from slack of Big vein, *soft*	14.07	2.73				
217	Coke, from Strip Vein, Hammondsville, Ohio.....	19.51	3.36	259	Coke from Jefferson Iron Works, Coal Shaft No 2, Steubenville, Jefferson Co., O	11.12	1.28
219	Leetonia bank, fair average........	8.47	1.08				
221	Washingtonville, Ohio, bank, average........	5.17	.61				

ANALYSES OF IRON ORES.

Record numbers.		Metallic iron.	Phosphorus.	Sulphur.	Silica.
1	Block ore, Perry county	42.4	.315	.86	13.92
13	Black Band ore, Mahoning county	24.4	.145	1.44	7.15
17	Calcined block ore, Ironton, Ohio	32.00	.62	.93	35.57
18	Limestone vein of ore, calcined, Ironton	43.60	.216	1.09	22.14
21	Under Coal No. 4, of Prof. Newberry, Columbiana Co	29.80	1.43	.86	10.06
31	Baird ore, Harrison township, Perry county, Ohio	42.35	.817	.75	14.82
37	Bird Run, Black Band, Tuscarawas Co	26.80	.196	1.08	11.89
39	Baird ore, Perry Co., O	29.00	.075	.78	19.77
43	Wampum ore, Himrod Furnace	32.90	.326	.73	21.17
140	Ore, 12 inches thick, Muskingum Co	38.60	.188	.241	5.38
141	Black Band ore, 15 feet thick, Stark Co	30.15	.592	.175	13.26
144	Iron carbonate, Holmes Co	31.35	.127	.352	19.58
145	Black Band ore, over Coal No. 5, Holmes county	19.25	.120	1.81	28.82
146	Heavy dep. of rough ore over Coal No. 5, Tuscarawas Co.	33.85	.513	.178	8.67
147	Iron ore, roasted, Hocking Co	59.50	.283	.167	8.81
149	Dugway ore, Athens Co	32.70	.361	.024	11.97
227	Rough ore from Pomeroy	3.33	....	....	24.75
212	Ore from near McConnellsville	32.83	....	....	13.66
211	S. E. ¼ Section 32, Morgan Co., O	16.50	....	....	12.53
210	N. W. ¼ Section 32, Morgan Co	22.66	....	....	5.42
151	Black Band, Carroll Co	25.65	.157	.46	12.39
148	Black Band ore, over Coal No. 5, Holmes Co	15.15	.071	.255	34.28
143	Black Band ore, Guernsey Co., O	12.60	.166	13.02	35.34
142	Black Band ore, Holmes Co., O	11.80	.16	6.99	37.52
139	Ore above Coal No. 5, Osnaburgh R. R. cut	29.70	....	....	16.52
38	Block ore, Perry Co	32.12	.208	....	9.52
34	Iron ore, from Perry Co., O	35.66	.335	....	5.67
33	Baird ore, Perry Co., O	15.00	.127	....	20.91
32	Section 9, Clayton township, Perry Co	33.33	.129	....	12.06

ANALYSES OF CLAYS.

Record numbers.		Water (combined).
35	Potters' clay, under Coal No. 4, from G. W. Brummage, Roseville, Section 9, Harrison township, Perry Co., Ohio	5.57
36	Potters' clay, under the horizon of Coal No. 5, Allen's Bank, Section 8, Harrison township, Perry Co., O	8.03
40	Potters' clay, on horizon of Coal No. 5, Section 10, Madison township, Perry Co., Ohio	7.39
160	Bolivar clay, from Island Fire-brick Works, Brown's Station, Jefferson Co., Ohio	8.90
161	Plastic clay, locality, etc., same as 160	9.67
162	Fire-clay, locality, etc., same as 160	6.52
163	Flint fire-clay, under Coal No. 5, C. E. Holden's mines, at Mineral Point, Tuscarawas Co	11.68
164	Sewer-pipe clay, N. U. Walker's Bank, 100 feet below Potters' clay, Walker's Station, Columbiana Co	8.17
165	Specimen of fire-clay, bank of Freeman Brothers, Freeman's Station, Jefferson Co	9.95
166	East Liverpool Pottery clay, bank of Frederick, Shenkle, Allen & Co., Columbiana Co	7.77
167	Ballou clay, horizon of Upper Freeport, or Bolivar clay, Zanesville Fire-brick Works, Putnam, Ohio	9.96
168	Sewer-pipe clay, Waynesburg, Stark Co.	7.07

ANALYSES OF IRON ORES—Continued.

Iron protoxide.	Iron sesquioxide.	Alumina.	Manganese oxide.	Lime.	Magnesia.	Carbonic acid.	Phosphoric acid.	Sulphur.	Water, organic matter.	Moisture.	Total.
1.50	58.45	3.71	2.93	1.53	.88	....	.72	.86	14.62	.90	100.02
2.52	31.26	4.62	.55	1.36	1.31	....	.33	1.44	47.56	1.85	99.95
....	45.72	6.10	1.09	2.85	1.12	....	1.423	.93	2.11	.48	97.39
....	62.30	7.86	.85	3.09	.92	....	.495	1.09	.78	.25	99.77
....	....	....	....	....	....	....	....	....	....	....	....
....	60.52	5.30	1.28	1.95	.51	....	1.874	.75	11.73	.123	99.96
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....
42.53	7.85	3.61	1.75	3.57	2.45	31.53	.431	.241	.53	.38	100.25
1.80	41.08	7.93	1.42	2.07	.65	3.47	1.362	.175	25.23	2.13	100.57
38.17	2.36	5.91	.42	2.67	2.42	28.11	.291	.352	.25	.22	100.75
19.85	5.43	13.31	.04	2.95	.94	15 46	.275	1.81	8.95	.58	98.41
43.11	.42	4.47	2.07	5.15	2.09	32.74	1.176	.178	.25	.12	100.44
....	85.02	2.88	.08	1 61	.09	....	.649	.167	....	.45	99.75
29.04	14.43	6.29	.83	6.10	2.83	25.68	.828	.024	2.41	.41	100.84
....	....	....	....	....	....	....	....	....	....	....	....
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....	....	....	....	....	....	....	....	....	....	....	....
15.29	4.64	....	....	....	....	....	....	....	25.50	....	....
.77	17.15	....	....	....	....	....	....	....	23 68	....	....
13.75	1.57	....	....	....	....	....	....	....	18.28	....	....
....	....	....	....	....	....	....	....	....	....	....	....
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ANALYSES OF CLAYS—Continued.

Iron sesquioxide.	Alumina.	Silica (combined).	Quartz sand.	Titanic acid.	Lime.	Magnesia.	Soda and lithia.	Potash.	Moisture.	Totals.
1.26	19.08	....	43.73	.29	.60	.63	2.14	2.14	.94	99.86
1.50	23.01	....	34.79	.35	.41	.62	Lithia, trace.	1.26	1.97	100.55
.99	23.05	....	35.85	.55	.58	.58	Lithia, trace.	1.45	1.11	100.90
1.66	24.97	29.22	31.34	1.30	.63	.40	Lithia, trace.	.28	1.69	100.39
2.77	28.69	35.73	16.07	.72	.77	1.41	.25	2.57	1.72	100.37
2.65	21.41	32.45	30.36	1.26	.58	.85	.21	2.89	1.47	100.65
.67	31.84	35.39	17.13	1.68	.50	.19	Lithia, trace.	.59	.69	100.36
2.41	27.88	39.03	15.50	1.26	.42	.68	.12	3.31	.76	99.54
1.94	30.10	37.92	13.80	1.85	.62	.53	Lithia, trace.	2.74	1.05	100.50
1.46	24.12	42.28	18.02	1.20	.59	.68	Lithia, trace.	2.42	.86	99.40
1.22	26.47	31.07	27.71	.94	.59	.32	Lithia, trace.	.99	1.04	100.31
2.86	15.89	16.20	52.69	.16	.59	.66	.27	2.23	1.03	99.65

ANALYSES OF CLAYS—Continued.

Record numbers.		Water (combined).
169	Fire-clay (from worked clay prepared for moulding), Island Siding Works, Jefferson Co	7.06
14	No. 1, blue clay, pottery clay, bank of Myers, Atchinson & Co., near N. Springfield, Summit Co	5.13
15	No. 2, white clay, pottery clay, locality same as No. 14, upper stratum (No. 14 is lower stratum)	5.56
16	No. 3, pottery clay, locality same as 14, a mixture of Nos. 2 and 1 in equal proportions	6.00
222	Sciotoville clay	13.77
223	Clay from Ironton Fire-brick Co.'s Works, under Coal No. 5, Ironton	....
224	Potters' clay, under Lower Mercer limestone, 4′ thick, H. & J. Stripes	6.63
225	Slip clay, from Albany, N. Y., used in Roseville potteries	....
226	Potters' clay, beneath Coal No. 6, Walker's Pottery, Roseville	5.08

ANALYSES OF SLAGS.

Record numbers.		Silica.
41	Slag, made from lake ore, coke and lime, no cinder, Lowellville, Mahoning Co., Ohio	30.66
44	Himrod Furnace slag	36.41
152	Slag, made with No. 1 iron, Hamden Furnace	52.90
153	Slag with pig-iron, Hamden Furnace	35.78
154	Slag, made with No. 2 iron, Cherry Valley Iron Works, Leetonia	53.71
155	Slag, made with silver-gray iron, Hamden Furnace	49.57

PIG-IRON ANALYSES.

Record numbers.		Silicon.
156	Pig-iron, Cherry Valley Iron Works, Leetonia, Ohio, No. 1 iron, made from grey limestone ore, Hamden Furnace	3.85
157	Hamden Furnace, Vinton Co., Ohio	2.33
158	No. 2 iron, other items same as 157	2.33
159	Silver-grey iron, other items same as No. 157	3.85

ANALYSES OF CLAYS—Continued.

Iron sesqui-oxide.	Alumina.	Silica (combined).	Quartz sand.	Titanic acid.	Lime.	Magnesia.	Soda and lithia.	Potash.	Moisture.	Totals.
4.42	20.80	31.00	29.16	97.	1.15	.72	.21	2.89	1.00	99.38
(19.	38)	(72.	10)	....	1.38	.23	....	....	1.12	99.34
(22.	61)	(68.	24)	....	.99	.11	....	....	1.00	98.51
(21.	37)	(69.	05)	....	1.70	.21	....	....	1.00	99.33
(40.	42)	(43.	78)	....	....	....	....	....	.82	....
....	....	36.16	18.07	....	....	....	....	....	....	....
(19.	23)	(72.	26)	....	....	....	....	....	.83	....
1.43	....	....	....	....	....	....	Soda. .72	3.17	....	....
(19.	31)	(69.	79)	....	....	....	....	....	.94	....

ANALYSES OF SLAGS—Continued.

Iron and alumina.	Lime.	Magnesia.	Oxide of manganese.	Sulphur.	Phosphorus.	Totals.
10.75	50.97	2.66	.60	2.21	Not determin'd	100.85
12.88	47.43	1.15	.72	1.68	" "	100.27
22 24	21.51	1.93	1.66	.16	.004	100.40
11.69	49.65	.82	.92	1.55	.009	100.41
22.94	20.67	2.09	Not determined	.19	Not determin'd	99.60
22.49	26.14	1.95	" "	.29	" "	100.44

PIG-IRON ANALYSES—Continued.

Total carbon.	Phosphorus.	Sulphur.	Manganese.	Iron by diff.	Totals.
3.033	.794	.016	1.480	90.827	100.000
3.245	.619	.037	.720	93.049	100.000
3.435	Not determined	Not determined	Not determined.	....	....
3.150	" "	" "	" "	....	....

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